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What happens when AI art eats itself?

Psychology
Why we trust confidence over competence

Health
The risks and rewards of becoming an older father

ADVERTISEMENT FEATURE

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

"As scientists, our duty is to secure the future of research for the generations that follow."

Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the medical community who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine CBE MD PhD FMedSci
Chair of the Medical Research Foundation

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FROM THE EDITOR

Okay, so I got a dog. A small German spitz called Zero (named after the ghost dog in *The Nightmare Before Christmas*. We picked her up from an animal sanctuary about six months ago and, naturally, she's taken over everything. But, I promise, that isn't why we've opted for a canine cover feature.

The idea actually took root a year or so ago, after speaking to Dr Claire Guest, the co-founder and CEO of the Medical Detection Dogs charity for our *Instant Genius* podcast. We talked about how dogs can sniff out cancer in their owners, or indeed in other people. In fact, Claire's dog actually saved her life by doing just that.

Not only is a dog's sense of smell so keen that, with the right training, they're able to sense the presence of cancer, but they can also, with certain medical conditions, spot when their owner is about to have a seizure. And do so minutes before any medical tech could, giving their owner vital time to get themselves into a place or position where they're less likely to hurt themselves. In light of these discoveries, the four-legged disease detectors have now been tasked with sniffing out malaria, COVID and even neurological conditions.

During our discussion, it struck me how much dogs are capable of knowing about us and it left me wondering: for all that they do for us, how well do we really know them? Fortunately, in the last decade there has been a surge of canine research, so we've devoted a healthy portion of this issue to deciphering what's really going on inside the minds of dogs and, for those of you with dogs, we've thrown in a few tips on how you can upgrade their daily lives.

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Earth
In this epic five-part series, Chris Packham uses cutting-edge CGI to walk you through our planet's tumultuous history. Expect rivers of lava, meteor storms and the ground tearing in two.
BBC Two, Mondays, 9pm
Also available on BBC iPlayer

The Conversation: Sleep
Almost everyone will have experienced trouble sleeping at some point, but women are 40 per cent more likely to experience sleep disruption than men. Presenter Kim Chakanetsa is joined by sleep scientists to find out what keeps us up at night.
BBC World Service, 24 July, 11:30am (BST)
Also available on BBC Sounds

Silced Bread
We're delighted to hear *Sliced Bread* is back on the airwaves. In this series, Greg Foot whips on a pair of barefoot shoes, tries out some expensive mattresses and looks into whether fancy painkillers really work.
BBC Radio 4
Also available on BBC Sounds

How do I stop hiccuping?
→p80

CONTRIBUTORS

CHRIS PACKHAM
He needs no introduction, but this month we spoke to Chris about his blockbuster new series *Earth*, which tells the story of our planet's most epic moments. → p22

DR AHMED ELGAMMAL
Artist and professor of computing at Rutgers University, Ahmed's work focuses on trying to build AIs that humans would truly consider to be creative. →p40

PROF ALEXANDRA HOROWITZ
Head of the dog cognition lab at Columbia University, Alexandra tackles our questions about what's really going on inside the minds of our best friends. →p56

DR ZAZIE TODD
Psychologist and author, Zazie specialises in animal behaviour and is particularly interested in what we can do to make our beloved pets happier. →p56

CONTACT US

Advertising
David.DSouza@ourmedia.co.uk
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Letters for publication
reply@sciencefocus.com
Editorial enquiries
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DR DEAN BURNETT

"HIGHER INTELLIGENCE MAKES YOU MORE AWARE OF WHAT YOU DON'T KNOW"

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EYE OPENER

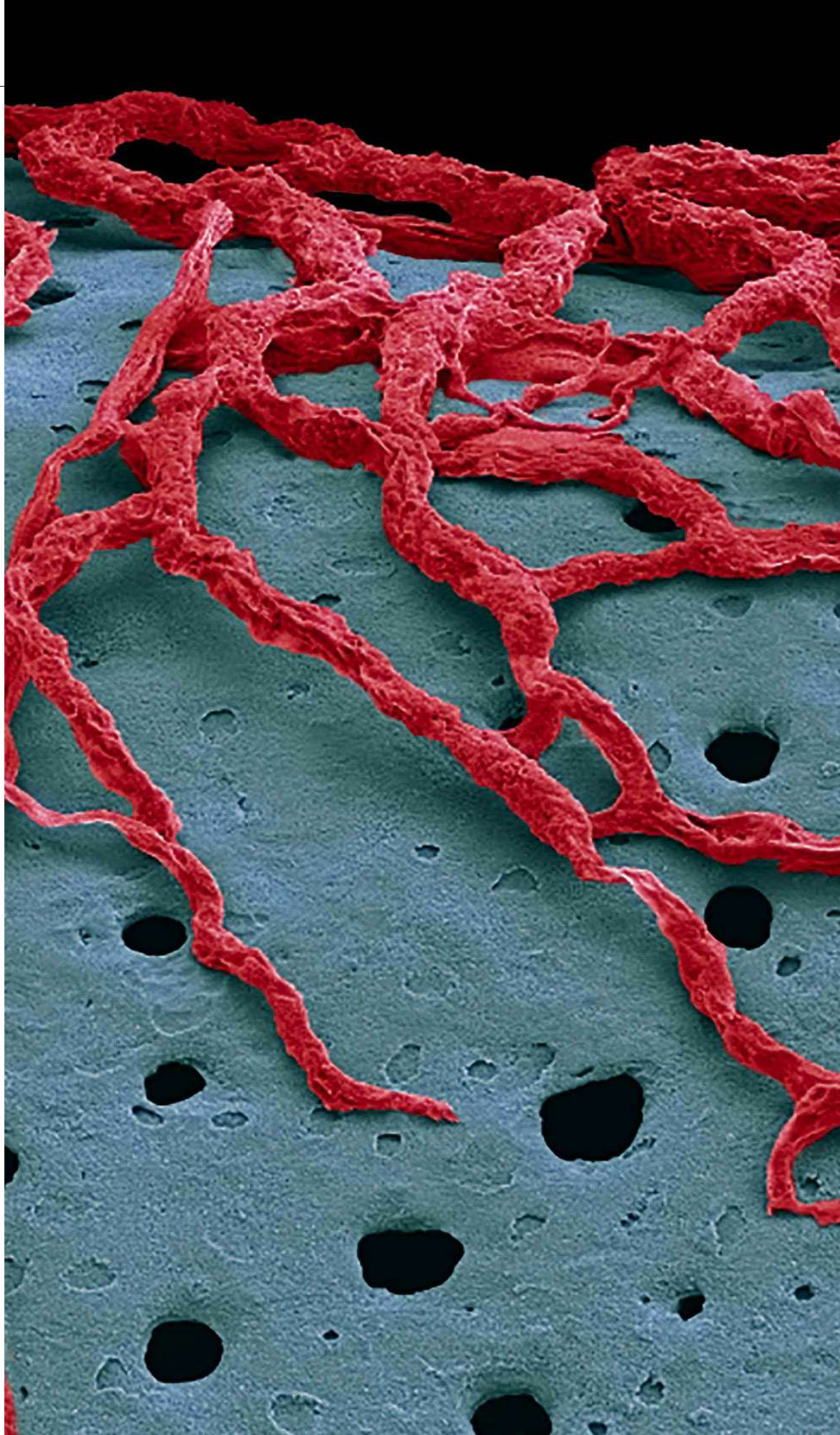
Blood and bone

The human body is a wealth of parts and connections. 206 bones in the skeleton, 86 billion neurons in the brain, roughly 25 quadrillion potential neural pathway routes... and yet there are just 20 arteries carrying your entire blood supply.

This image shows the periosteal arteries (in red). It was captured using a scanning electron micrograph, a device used to obtain close-up images of tiny biological samples by using electrons as a source of illumination.

The periosteal arteries form a network of vessels, known as the periosteum, which covers the length of a bone's shaft (seen here in blue). The periosteum plays an integral role in bone growth during childhood and bone repair.

The main role of the periosteal arteries is to supply blood to the outer layers of the bone and the skeletal muscles it's attached to. As well as supplying the skeletal system with oxygen and nutrients, the arteries also remove metabolites from the bones.



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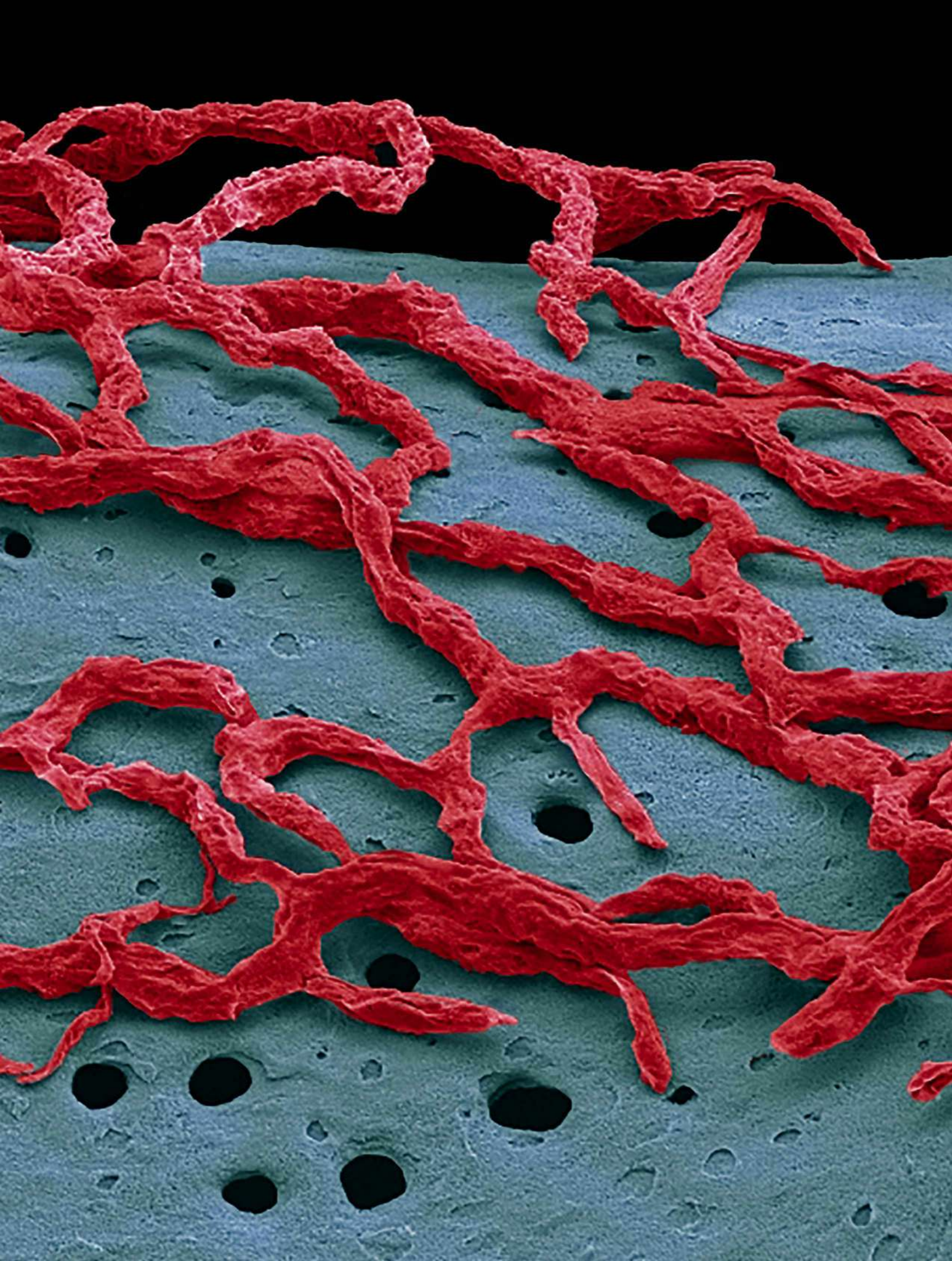

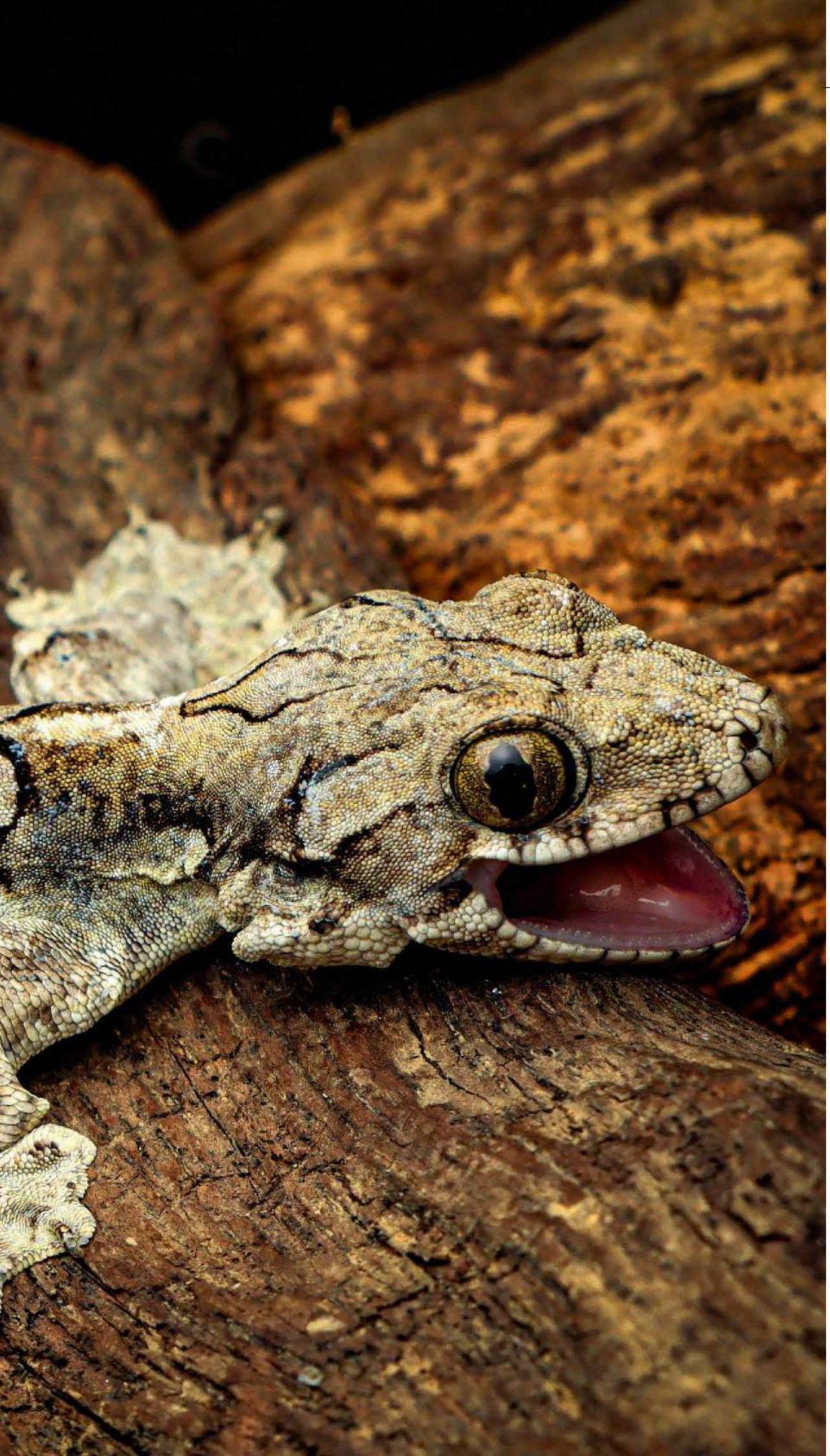

EYE OPENER

Who needs wings?

MIZORAM, INDIA

This little critter with the cheeky grin is a Mizoram parachute gecko, *Gekko mizoramensis*, a previously unknown species of gliding gecko from the tropical forests of northern India. It's one of a handful of species capable of gliding, which it does using a combination of skin flaps and webbed feet. The flattened tail, meanwhile, helps it to steer.

Although a single specimen of this species was collected over two decades ago, it's only recently been recognised as a new species. And it's an exciting discovery for more than one reason. "Parachute geckos are not common, at least in India," explains PhD student Zeeshan Mirza, who co-authored the paper describing the new species. "Even when most species have a wide distribution, they're not locally common, which could be because of their secretive lives."

Thick vegetation has made assessing biodiversity in the region difficult, but Mirza believes the dense forest is hiding more secrets. "I'm sure there are many more species to be discovered. On my trip, we discovered six new reptiles!"

ZEESHAN A MIRZA

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FEEDBACK

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND OUR MAGAZINE

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LETTER OF THE MONTH

Will the introduction of biometric identification mean you have to keep dabbing the dabs off your devices?

Wipe off your prints

I found Dr Peter Bentley's Reality Check article on passwords (June, p36) very interesting. My mother is 88 years old and is a convert to the fingerprint form of self-identification. But I've begun to wonder whether this form of security is actually as good as the article stated.

A finger that's pressed against glass or plastic will leave residue on the material from sweat and skin oil. The police have, for decades, used techniques to identify and record fingerprints left at crime scenes using these residues. It's not far-fetched, I believe, to imagine that the criminal fraternity would have access to the same technology, or certainly a version of it. Once captured, the fingerprint could be replicated on soft plastic with the use of a 3D printer and then used on a stolen smartphone or tablet.

Perhaps people should be advised to wipe their screens after logging on this way. I only hope I'm not the first person to think of this idea and that I haven't given villains any ideas!

Simon Smith, Cambridge

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins ***a trio of paperback science books***. Put pen to paper (or fingertips to keyboard) and you could get your hands on *Life as we Made it* by Beth Shapiro; *Thinking Better* by Marcus du Sautoy; and *Ending Hunger* by Anthony Warner.

Is the inside coming out?

With regard to your cover feature, The Mysteries of Earth's Core (June, p66), I once came across a rather unnerving article on the possibility of planetary core expansion.

It was based on the theory that some planets are approximately the same density all the way through, while others, such as Earth, have denser cores than the outer mantle. The theory suggests that, under certain circumstances, one type of planetary core may change to another, and Earth's core could suddenly expand outwards to attain the same density as the rest of the planetary body.

One scientist even suggested that so much energy would be released by such an event that it would blow the continents into orbit! Another suggested that it was unlikely that anything larger than a microbe would be left alive. Is this possible?

Paul Byatt, via email

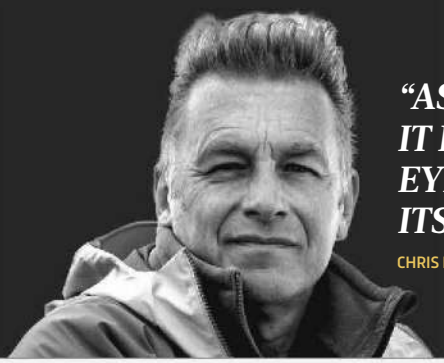
Seismologist Dr Dan Frost replies...
Don't worry about planetary expansion blowing us all into space, this hypothesis is no longer considered likely.

A growing Earth was suggested to explain the movement of continents and the growth of oceans at the mid-ocean ridges, which today we explain by the great cycling of Earth's crust and mantle, better known as plate tectonics.

We don't expect Earth's core to expand, either. Solid iron is slightly more dense than liquid iron, so if anything, the planet might shrink slightly as it cools. Solid iron does exist in different solid states, some denser than others, but the mass of the mantle on top of the core keeps all of that iron squeezed into the smallest volume possible. Our core will get colder and become less active, but it's definitely staying put.

Pick up your mess

I really enjoy *BBC Science Focus*, which my grandparents are kind enough to buy me a subscription to. I especially like the



"AS THE BIRD PASSED BY, IT LOOKED RIGHT INTO MY EYES... AND THEN EVACUATED ITS BOWELS ALL OVER ME"

CHRIS PACKHAM, P22

Sudden planetary expansion could have disastrous effects. Thankfully, it's pretty unlikely

GETTY IMAGES X2, BBC STUDIOS

technology reviews and Dr Kate Darling's articles on human-robot interaction! I don't think we should be investing so much time and money into trying to send astronauts to Mars, however. Space exploration is exciting, but we shouldn't do it right now – especially with the problem of climate change that we're facing. Shouldn't we solve the problems we've created on this planet, before we go looking at others?

I'm shocked by the amount of waste left on the Moon from previous missions and all the broken bits of hardware lying on Mars. The main objective of our next crewed mission to the Moon (or our first to Mars) should be a litter pick. We ought to keep other planets clean and unpolluted for future generations of explorers.

William Rawlings, aged 14, Norfolk

Remembered

Last issue we mentioned the adventurer Hamish Harding in our infographic on the Mariana Trench. Sadly, the magazine went to press before news broke of the catastrophic implosion of the Titan submersible and the deaths of all those, including Harding, who were aboard. We'd like to extend our condolences to his family and apologise for any offence this may have caused.

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Editor & brand lead Daniel Bennett
Managing editor Robert Banino
Commissioning editor Jason Goodyer
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Staff writers Alex Hughes, Holly Spanner

ART

Art editor Joe Eden
Picture & asset manager James Cutmore

CONTRIBUTORS

Hayley Bennett, Daniel Bright, Steven Boswell, Dean Burnett, Lewis Dartnell, Emma Davies, Stephen Dobie, Sam Freeman, Michelle Griffin, Matt Holland, Alexandra Horowitz, Christian Jarrett, Stephen Kelly, Pete Lawrence, Bernard Leonardo, Katie Mack, Nish Manek, James Olstein, Stephanie Organ, Helen Pilcher, Jenny Price, James Round, Colin Stuart, Zazie Todd, Ian Taylor, Luis Villazon, Joe Waldron, Chiara Xie.

ADVERTISING & MARKETING

Business development manager David D'Souza
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TECHNOLOGY

Head of apps and digital edition marketing Mark Summerton
Tech director Azir Razzak

INSERTS

Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION

Director of licensing and syndication Tim Hudson
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Production director Sarah Powell
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PUBLISHING

Publisher Andrew Davies
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BBC STUDIOS, UK PUBLISHING

Chair, editorial review boards Nicholas Brett
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EDITORIAL COMPLAINTS

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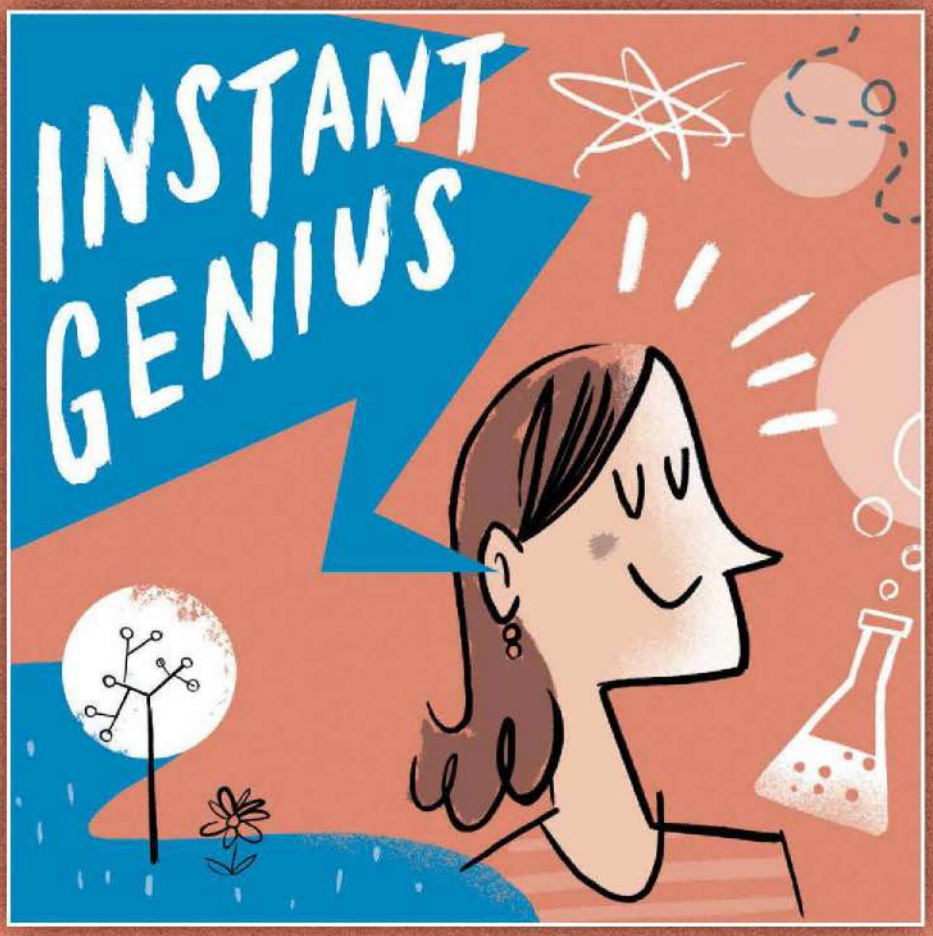

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with
Dr Thomas Curran

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with
Dr Helen Czerski

DISCOVERIES

"We've never seen such dramatic changes in other supermassive black holes"

Dr Frédéric Marin **p18**

The Green Bank Telescope, in West Virginia, US, was just one of the instruments used to detect low-frequency gravitational waves

JAY YOUNG/GREEN BANK OBSERVATORY

COSMOLOGY

CATCH A WAVE

Greater insights into gravitational waves revealed by data captured in galaxy-sized net **p14**

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AI PREDICTS FUTURE HITS

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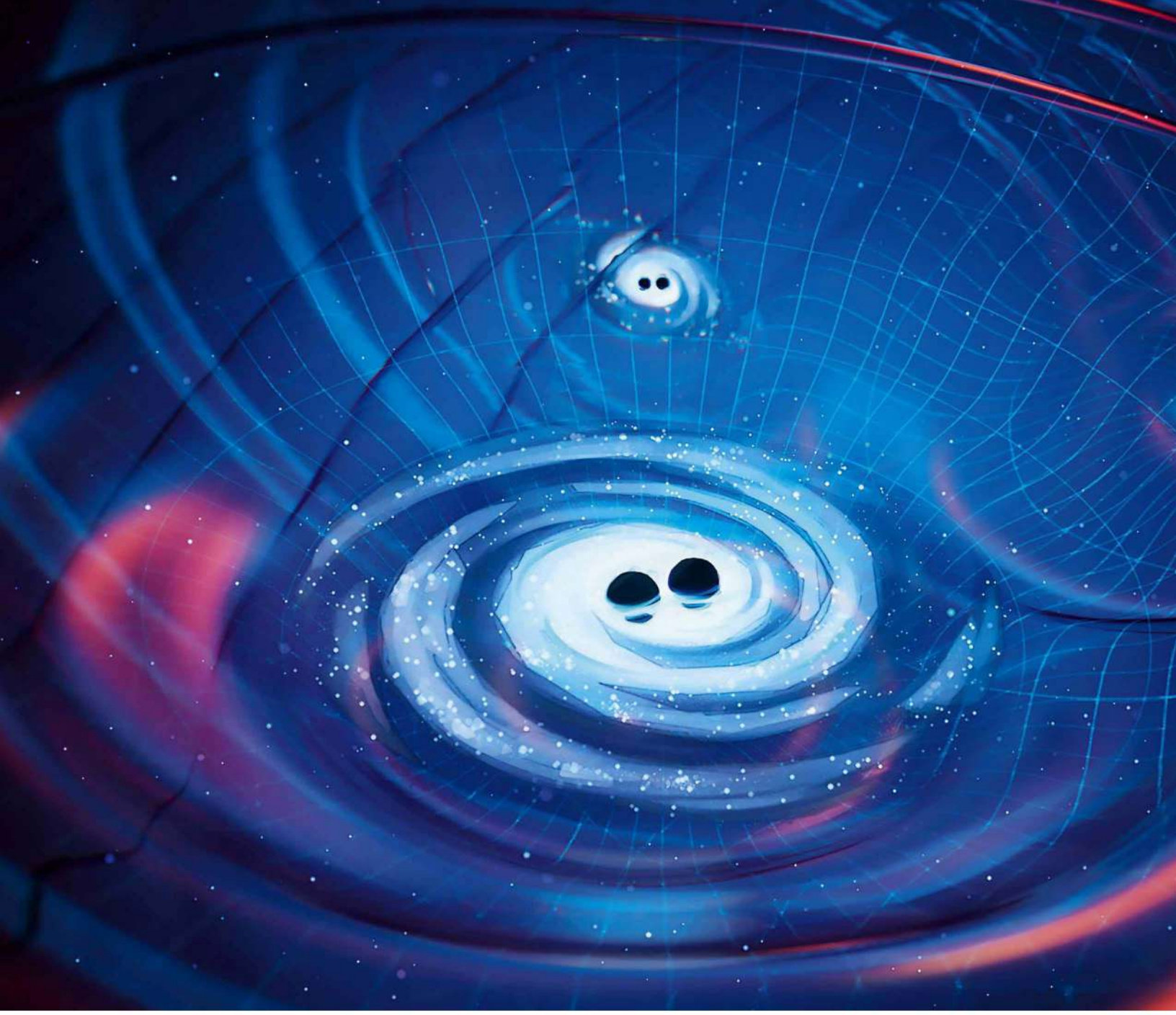


COSMOLOGY

GRAVITATIONAL RIPPLES COULD HELP CRACK THE UNIVERSE'S SECRETS

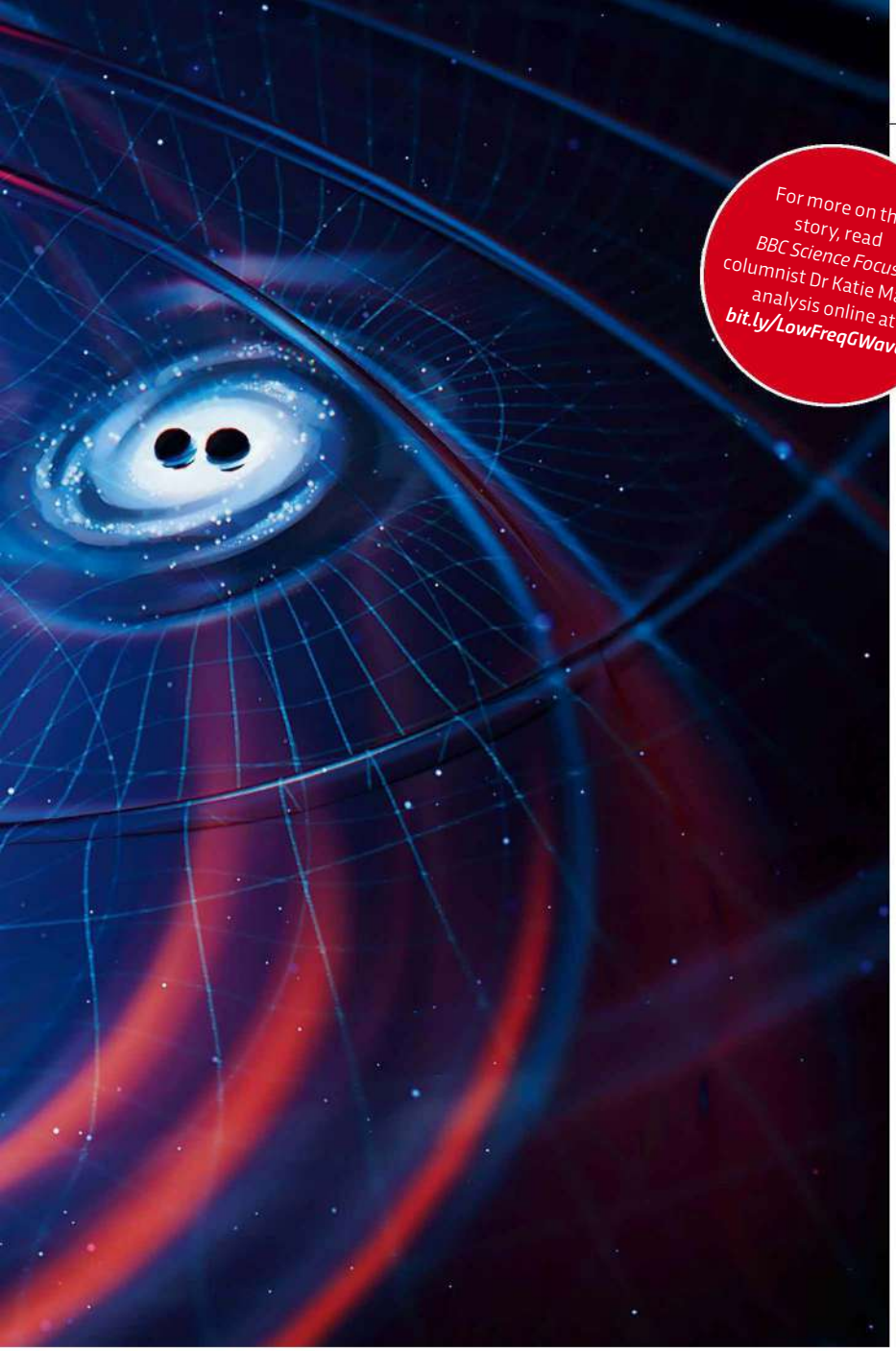
New findings provide evidence of a 'background hum' produced by low-frequency gravitational waves rippling across spacetime

An international team of scientists has found evidence that suggests Earth, and indeed everything in the Universe, is afloat on a constantly rippling sea of low-frequency gravitational waves.

The findings, announced in a series of papers published in *The Astrophysical Journal Letters* were made by the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), a team of researchers from more than 50 institutions in the US and abroad. Together, the papers provide the first evidence of a gravitational wave background – essentially, a soup of spacetime distortions that pervade the entire Universe.

"This is the first-ever evidence for the gravitational wave background. We've opened a new window of observation on the Universe," said NANOGrav scientist Dr Chiara Mingarelli.

OLENA SHMAHALO/NANOGRAV



For more on this story, read BBC Science Focus's columnist Dr Katie Mack's analysis online at **bit.ly/LowFreqGWaves**

ABOVE The gravitational effects produced by enormous black holes circling each other send distortions rippling across the fabric of spacetime

"We've opened up a new window of observation on the Universe"

Gravity waves were first predicted by Albert Einstein in 1916, but their existence wasn't confirmed until 2015 when they were first detected by the Laser Interferometer Gravitational-wave Observatory (LIGO).

Those waves were of much higher frequencies and come along once in a while, like the waves a surfer might look to catch and ride back to the beach (except created by the collision of two black holes in deep space). The lower-frequency gravitational waves picked up by the NANOGrav scientists are smaller and constant, more akin to the ripples you see on the surface of a calm ocean.

"People compare this signal to more of a background murmur, as opposed to the shouts that LIGO picks up," said Katerina Chatziioannou, an assistant professor of physics at Caltech and a member of the NANOGrav team.

If confirmed, the existence of a gravitational wave background could lead to answers to some of cosmology's biggest questions, from the fate of colliding supermassive black holes to the frequency of galaxy mergers, and maybe even the birth of the Universe.

The higher-frequency gravitational waves detected by LIGO come from smaller pairs of black holes circling each other rapidly in the final seconds before they collide. Lower-frequency gravitational waves are thought to be generated by huge black holes at the hearts of galaxies, up to billions of times the mass of the Sun, that lumber around each slowly and have millions of years to go before they merge.

To detect the lower frequency waves the NANOGrav team used a pulsar timing array (PTA), which measures the radio pulses that spinning neutron stars (pulsars) emit at regular intervals.

When a gravitational wave passes between a pulsar and Earth, the distortions it causes in spacetime cause the pulse to arrive earlier or later than expected… albeit by billionths of a second. By analysing these tiny differences, astronomers are able to determine the nature of the gravitational waves causing the change.

The NANOGrav team used observations of 67 carefully chosen pulsars taken by radio telescopes including the Green Bank Observatory in West Virginia, the Very Large Array in New Mexico, and the Arecibo Observatory in Puerto Rico to effectively create a gravitational wave detector the size of our galaxy.

The team now plans to work with other researchers across Europe, India, China and Australia to investigate the gravitational wave background in more detail.

"Now that we have evidence for [low-frequency] gravitational waves, the next step is to use our observations to study the sources producing this hum," said Sarah Vigeland, an assistant professor of astrophysics at the University of Wisconsin-Milwaukee and chair of the NANOGrav team.

The cost of switching to renewables, such as offshore wind, is high in the short term, but has long-term benefits

ENERGY

THE COSTS OF SWITCHING TO RENEWABLE ENERGY WILL HIT THE SUPER-WEALTHY HARDEST

A new study says a future fuelled by sustainable energy is possible, if the top 10 per cent are prepared to accept some losses

The urgent need for solutions to the climate crisis was made clear in the International Panel on Climate Change's climate report published earlier this year, but who will pay for them? According to a new study, it will be the super-wealthy.

According to the study, published in the journal *Joule*, a transition to renewable energy would have a low impact on the majority of people – despite previous assumptions that moving away from fossil fuels would negatively impact retirement plans and savings.

Instead, the team of economists from France and the US estimated that the biggest losses in high-income countries would be to the wealthiest citizens – and even these losses would account for a small percentage of their total wealth.

"There's this big question of who's winning and who's losing from the transition and from climate change in general," says the study's co-first author Lucas Chancel, an economics professor at Sciences Po, Paris.

"Even though our results are simple, they were not present in research or public debates before. This work is one step forward in understanding the winners and losers from the point of view of the assets that might be at risk in this transition."

> **"The poorest half of citizens would only suffer 3.5% of the financial losses"**

The study found similar results in both the US and the UK, as well as other countries in Europe. In these nations, an estimated two-thirds of financial losses would affect the wealthiest 10 per cent of the population.

Half of the assets lost would affect the top one per cent of wealth holders. Within this super-wealthy group, the losses would make up less than one per cent of the individuals' net wealth.

Meanwhile, the poorest half of citizens would only suffer 3.5 per cent of the financial losses. At a much lower rate of loss, the economists argue that these damages would be more easily compensated by governments. They propose carbon emission taxes as one way of raising compensation funds.

According to the UN, a transition to renewables is likely to financially benefit everyone in the long term. Short-term investments in new infrastructure will pay off as a more resilient system helps to reduce the impacts of pollution and climate change – saving the world £3.3 trillion (or $4.2 trillion) per year by 2030.

GETTY IMAGES X2

BIOLOGY

WORMS CAUGHT HITCHING RIDES ON BEES BY USING ELECTRIC FIELDS

As well as hitchhiking, the nematode worms also form conga lines

Ever wished you could just leap onto the nearest travelling object to cut down your journey time? Well, scientists have just discovered that a microscopic worm can use electric fields to leap onto moving creatures. Much like hitchhiking for humans, this ability allows the worms to save energy and travel further.

"When you're very small, the world is a very different place," entomologist and broadcaster Prof Adam Hart, who was not involved in the study, told *BBC Science Focus*. "*Caenorhabditis elegans* is an incredibly well-studied creature and yet even with all that attention we can still find something new."

The 1mm-long *C. elegans* worms, which are commonly found in the soil, were found attempting to fling themselves from Petri dishes in the labs of Hiroshima University and Hokkaido University, Japan. So the scientists rubbed pollen on a bumblebee to build an electric charge, and watched as the worms jumped aboard.

Published in the journal *Current Biology*, the study also found that worms can get on each others' 'shoulders' in a single column, each worm lifting the one below. In this tiny conga-line arrangement, as many as 80 worms can jump the electric field in one go.

The scientists discovered that the worms jump at an average speed of 0.86 metres per second, which is about the same as human walking speed. However, this speed increases as the intensity of the electric field grows.

Pollinators like butterflies, bees and hummingbirds are known to form electric fields with the plants that they pollinate to attract the pollen to them, making them electrically charged. But, until now, scientists have not known whether these fields are used between animals – let alone as a way for tiny creatures to hop onto much larger ones.

"That we discovered this by researchers observing *C. elegans* stuck to the lids of Petri dishes shows just how important the first step of the scientific method – observation – really is," said Hart.

Medical models: C. elegans

Caenorhabditis elegans have served an important role in medical research since the 1970s. From genome stability and DNA repair mechanisms to Parkinson's and memory, we have these little worms to thank for much of our learning about human physiology and diseases.

Caenorhabditis elegans **(seen here under a coloured scanning electron microscope) live in soil and can reproduce by self-fertilisation to produce identical offspring**

SPACE

A RADIATION 'ECHO' FROM A SUPERMASSIVE BLACK HOLE IS SPREADING ACROSS THE GALAXY

The sleeping cosmological giant woke up around 200 years ago and devoured everything in the vicinity, releasing intense amounts of radiation in the process

Around 200 years ago, Sagittarius A* (Sgr A*), the black hole at the centre of the Milky Way, suddenly burst into life. It began consuming as much nearby cosmic material as it could, and released radiation a million times stronger than it releases today, before returning to a dormant state. That's according to a new discovery made by researchers at the Strasbourg Astronomical Observatory in France, using measurements taken by NASA's Imaging X-ray Polarimetry Explorer (IXPE) satellite.

The researchers wanted to know why the energetic X-rays emitted by galactic molecular clouds located near Sgr A* shine so brightly. The answer lies in the fact that Sgr A*, which is four million times more massive than the Sun, emerged from a long period of dormancy in the early 19th century to begin a year-long feeding frenzy – causing it to emit massive amounts of radiation.

Data from NASA's IXPE (orange) and Chandra (purple) instruments has been combined to zoom in on and highlight the X-rays in the area around Sgr A* (top)

It's this radiation that's now being reflected by the galactic molecular clouds in the form of intense X-rays.

Although black holes suck in and trap all light that enters their event horizons, the enormous forces they generate cause nearby matter to heat up to millions of degrees. This results in the emission of radio waves and X-rays.

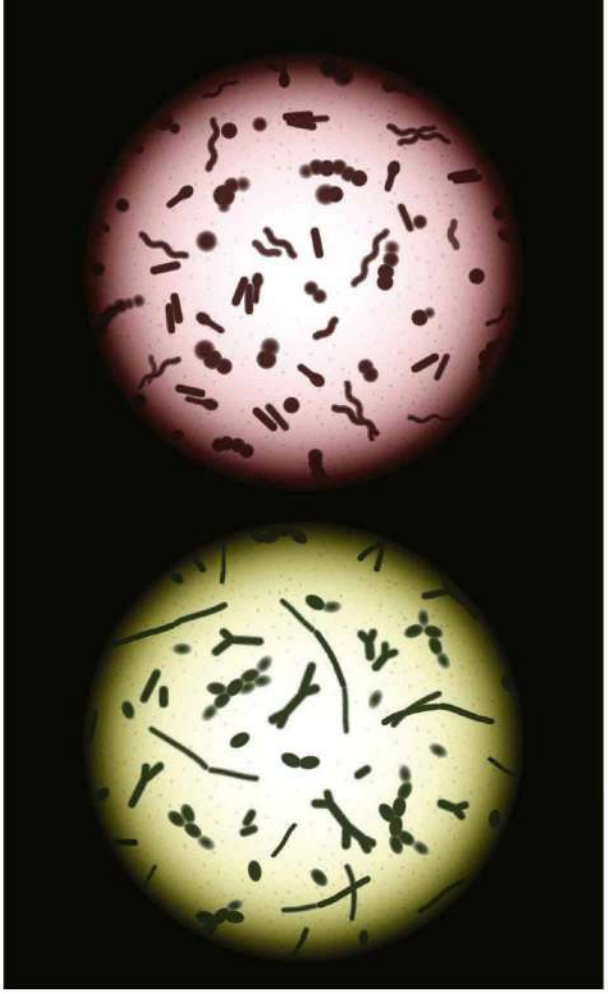
The researchers say the effect was so dramatic that it was comparable to a lone glow-worm buzzing around a forest at night, suddenly becoming as bright as the Sun.

"This is a unique observation, we've never seen such dramatic changes in other supermassive black holes," research leader Dr Frédéric Marin told *BBC Science Focus*.

"It can potentially tell us a lot about the accretion cycles of supermassive black holes and help us to understand how they can shape the galaxy that surrounds them by pushing gas around and suppressing star formation."

The team now plans to investigate the exact mechanisms that allowed Sgr A* to switch from its dormant state into a temporarily voracious one. "Our next goal is to understand how the black hole woke up for just a year. Maybe a star, or a group of stars, passing by, caused the accretion of interstellar dust clouds," said Marin.

IXPE/NASA/MSFC/F MARIN ET AL/CHANDRA, GETTY IMAGES X2



MEDICINE

SCIENTISTS TO TEST 'POO TRANSPLANT' PILLS IN GROUND-BREAKING GUT HEALTH TRIAL

Your number twos could be the number-one defence against liver disease

The UK is set to begin a clinical trial to fight advanced liver disease with a new tablet – made of faeces. The 'crapsules' contain the good bacteria from the dried and powdered faeces of healthy volunteers. Apparently, they don't smell or taste of poo.

"There's an urgent and unmet need to tackle infection and antimicrobial resistance in chronic liver disease," said Dr Lindsey Edwards, senior lecturer in inflammation biology at King's College London. "If we can boost liver patients' own immunity to reduce infections by modifying the microbiome, we can reduce the need for the prescription of antibiotics."

The trial aims to establish whether faecal microbiota transplants (FMT) can reduce the likelihood of infection in liver disease patients. The scientists also hope the trial will confirm initial findings that FMT can improve gut health in the microbiome.

ABOVE LEFT
Faecal matter from healthy volunteers is dried and powdered to form the 'crapsules'

ABOVE RIGHT
Samples of 'good' (on green) and bad (on red) microbiota, seen under a microscope

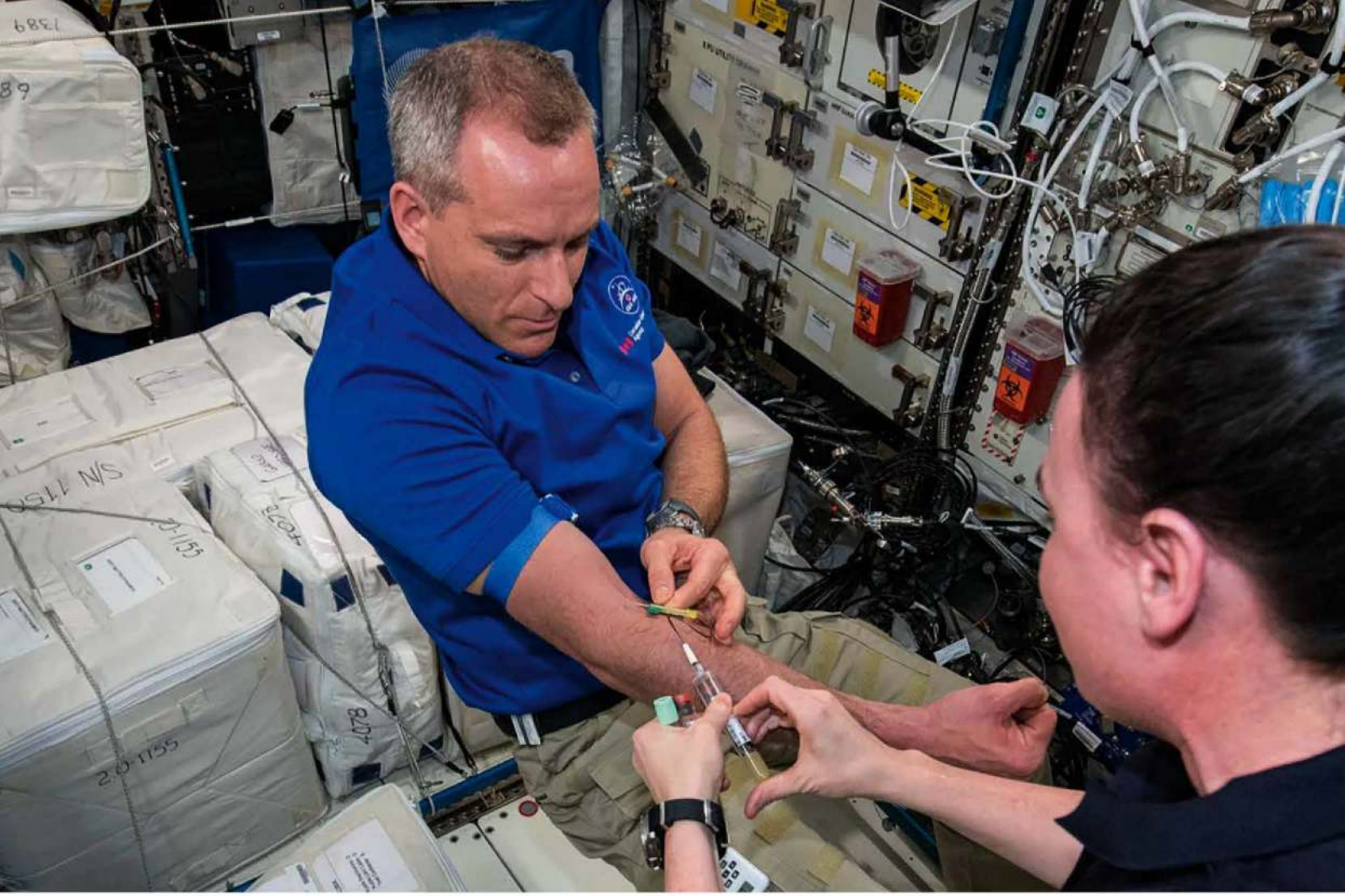
The advanced stage of liver disease, known as cirrhosis, is irreversible. It's the third most common cause of death in the UK, as well as the third most common reason that people have to stop working.

People with cirrhosis have 'bad' bacteria in their bowels that make them more vulnerable to infections, which are more severe and can even be fatal. Scientists hope that this bad bacteria could be replaced with the 'good' bacteria in the pills.

The trial, led by King's College London, will involve 300 participants from across the UK. Over the course of two years, they'll be given either an FMT tablet or a placebo to take every three months.

The news of the UK trial brings hope to cirrhosis sufferers, whose only current option is a liver transplant. Liver transplants, however, aren't possible if the patient also has an antimicrobial-resistant infection, which is common in cirrhosis patients given their high exposure to antibiotics.

According to Pamela Healy, CEO of the British Liver Trust, in the future this tablet could help tackle the antimicrobial infections themselves. "Finding new, effective ways to treat resistant bacteria is one of the most important challenges in global medicine and this could provide a solution that could save healthcare systems across the world millions of pounds."



MEDICINE

SCIENTISTS DISCOVER WHY SPACE TRAVEL WEAKENS ASTRONAUTS' IMMUNE SYSTEMS

Astronauts routinely break out in rashes or get ill while aboard the International Space Station. Now we know why

A new study shows that space travel changes how the genes in our white blood cells work, preventing them from recognising and combating infections.

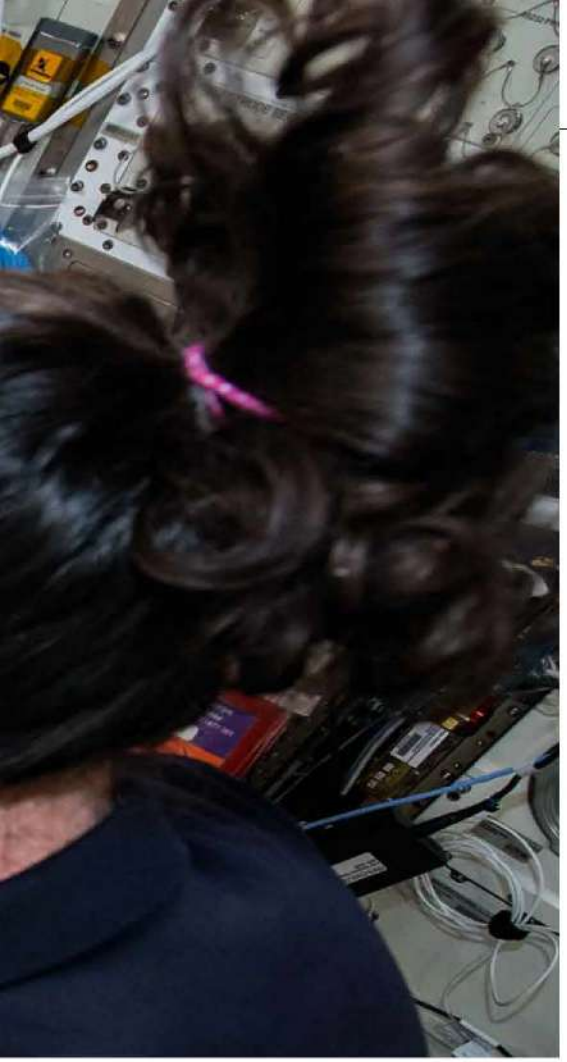
"These results are important considerations of the risks to health during spaceflight and space exploration," Myles Harris, coordinator of the Space Health Risks Research Group at University College London, who was not involved in the study, told *BBC Science Focus*.

The study, published in *Frontiers in Immunology*, describes how the rapidly decreasing strength of our immune systems in space is likely caused by a phenomenon known as 'fluid shift'. Fluid shift involves blood plasma, which transports white blood cells around the body, moving from the lower body to the upper body due to the microgravity of being in space. It's thought that this fluid shift alters the expression of over 15,000 genes within our white blood cells as well as the volume of both the blood plasma and the white blood cells.

"It's thought that this fluid shift alters the expression of over 15,000 genes within our white blood cells"

But it's not all bad news – as long as you return to Earth. Within one year of returning from a six-month stint on the International Space Station (ISS), astronauts' volumes of white blood cells return to normal. This is why astronauts are more vulnerable to infection during their

NASA/JSC, GETTY IMAGES



ABOVE A blood sample is taken from Canadian astronaut David Saint-Jacques aboard the ISS

first month back on Earth. Individuals' specific recovery times are likely to depend on personal factors, but research on this has yet to take place.

The research team, from the University of Ottawa, Canada, studied white blood cell genes from 14 astronauts who had spent 4.5-6.5 months aboard the ISS. Before, during and after the flight, the astronauts had 4ml (less than a teaspoon) of blood drawn 10 times.

"A weaker immunity increases the risk of infectious diseases, limiting astronauts' ability to perform their demanding missions in space," said Dr Guy Trudel, one of the study's authors.

"If an infection or an immune-related condition was to evolve to a severe state requiring medical care, astronauts, while in space, would have limited access to care, medication or evacuation."

The next step will be designing ways to prevent immune system suppression during long-duration space flights. According to Harris, this "would also make valuable contributions to the design of personalised medicine on Earth."

NEUROSCIENCE

AI USES BRAINWAVES TO PERFECT YOUR PERSONALISED PLAYLIST

Your mood and energy levels may reveal your preferred musical genres to streaming services

Lady Gaga's *Bad Romance*. Beyoncé's *Crazy in Love*. Adele's *Rolling in the Deep*. They're all massive global hit songs, but what makes them so successful?

A team of researchers in the US might be on the way to finding out after they used a machine learning artificial intelligence to predict hit songs with 97 per cent accuracy.

They did it by fitting sensors to volunteers to monitor their brainwaves as they listened to 24 pop songs. The approach is known as 'neuroforecasting' and aims to record the neural activity of the participants as they experience a sound, act or feeling in parts of the brain associated with mood and energy.

Once they had the data, the team used machine learning techniques and computational models to line up the participants' neurophysical responses to how they rated the songs. The researchers then used a machine learning algorithm to figure out what was going on.

"That the neural activity of 33 people can predict if millions of others listened to new songs is quite amazing. Nothing close to this accuracy has ever been shown before," said research lead Prof Paul Zak of California's Claremont Graduate University.

The researchers suggest that the technique may help streaming services to predict the genres and styles that listeners are more interested in.

"This means that streaming services can readily identify new songs that are likely to be hits for people's playlists more efficiently, making the streaming services' jobs easier and delighting listeners," Zak said.

The study was not without limitations. It only included a small number of songs and styles, and the sample size, ethnic diversity and age span of the participants was relatively small.

However, the team believes that the same technique could be applied in the study of other art forms.

Lady Gaga performs in Germany during her summer stadium tour in 2022

CHRIS PACKHAM VERSUS THE WORLD

After conquering wildlife programming, presenter **Chris Packham** is taking on the planet in *Earth*, a BBC series that sheds new light on the history of our home. He talks **Noa Leach** through the show's surprising science – and his guilty conscience

The camera pans around a purple mountain rising through a lush green forest. But the film glitches… something is wrong. The scene flickers with a hellish inverse: a deadly volcanic eruption. The Earth's crust splits and red light bleeds from its opening. Deadly rivers of lava veil the now-black rock, and ash and toxic gases spill into the air.

This fiery inferno is the deadliest volcanic event in Earth's history, around 250 million years ago. It's just one of many moments that have brought the planet we call home close to death – and one of the five key events that shape the BBC's new *Earth* series.

This is the BBC Natural History Unit's usual output reborn as a forensic crime thriller, with fossils as evidence. With Chris Packham presenting, *Earth* exposes the clues hidden in fossil records that reveal all the times the planet – and our long-gone ancestors – have *almost* been destroyed over the last 4.5 billion years.

In this way, *Earth* aims to show that our future has already happened, with the current climate crisis eerily echoing the past. But will we survive it this time around? We got the verdict from Chris Packham himself…

YOUR NEW SERIES COVERS BILLIONS OF YEARS OF HISTORY. HOW ON, AHEM, EARTH DID YOU FIT THAT INTO ONE SERIES?

Our mission was to present the series as a biography of our planet. It's not just about how Earth was born, but its bumpy life journey – akin to how it met its first girlfriend, got married, then divorced and then happily remarried.

We wanted to highlight the moments that had a significant impact on the planet – the key geological, planetary and life forces. And how they interact.

For example, when the lava was beneath the surface of the planet, it was burning coal, which raised the temperature of the planet by 10°C. This was catastrophic. But now here we are digging it up and burning it again!

However, *Earth* is very much a science series – it's not just about climate breakdown. There's a lot of variety in there, with a lot of surprising facts thrown into the mix.

TRY US. BLOW OUR SOCKS OFF WITH SOME SCIENCE FACTS

Well, there used to be alligators at the North Pole during a planetary warming event. On another occasion, the whole planet almost froze in what's called a →

BBC STUDIOS

BBC
TWO
Watch *Earth* on BBC Two, Mondays at 9pm, and catch-up on previous episodes with BBC iPlayer
BBC
iPLAYER

→ Snowball Earth event – it was pretty much glaciated down to the equator!

AND WHAT DID YOU PERSONALLY LEARN THAT WAS NEW?

A lot. One thing was that fungi, not plants, originally dominated the land – it's fascinating! Millions of years ago, plants were effectively trapped in the sea and couldn't get onto the land. It was fungi that took those first steps due to their autotrophic nature – they can essentially remove ingredients from bare rock. One of these species, Prototaxites, had fungal spikes that were eight metres high (26 feet).

Funnily enough, fossils of this fungi were hidden in museums for ages – we just didn't know it. They were thought to be tree remains, but it took one person to think, "I'll have another look at that." Using new technology, they found it wasn't a plant fossil, but a fungi fossil.

DID LEARNING SO MUCH LEAVE YOU WITH MORE QUESTIONS THAN ANSWERS?

I think so. This happens when you love learning new things. It's really exciting that due to contemporary technology and its affordability, we are learning a lot, and more quickly than ever before. It's likely that I know more about the Earth than my father or grandfather in their lifetimes because I can comfortably pick up something like *BBC Science Focus* and see some staggering new story.

But the greatest thrill is that you and I will go to our graves not having all the answers. It leaves room for the imagination.

WHAT WAS YOUR FAVOURITE MOMENT DURING FILMING?

I got pooped on – by a giant condor! Magnificent birds! This massive condor floated down while I stood on an escarpment in Chile. As the bird passed by, it looked right into my eyes… and then evacuated its bowels all over me.

I was elated! Absolutely elated! If you get pooed on by an animal, you know you're really close to it – that's what wildlife is all about!

***EARTH* COVERS THE START OF THE PLANET'S HISTORY, BUT WHAT ABOUT ITS END? DOES THAT WORRY YOU MUCH?**

We know the *planet* will end when the Sun expands and Earth gets too hot. But that's a long way off.

I think most people see mountain ranges having some kind of permanence. But they're very new in geological time – and really fragile!

We're a fortunate species to have evolved at a point where there's been incredible stability in the environment. However, that stability could be undone at any point by an asteroid or supervolcano. If Yellowstone just cracked open and got going, it really wouldn't be atypical of Earth's history. Although it would certainly change our role on the planet!

Ultimately, it's all unpredictable. And I don't mind that. I don't like to think humans are the be-all and end-all of life and the Universe. We should respect our own species' fragility. We're really very special and lucky. We ought to appreciate that a bit more.

AS PART OF THIS, DO YOU A FEEL PERSONAL RESPONSIBILITY TO HIGHLIGHT HOW OUR CLIMATE IS CHANGING?

Of course. I do see it as my job to amplify the science.

As an older person, I feel incredibly guilty. But it's a great fuel. I don't feel I've done enough, it's like I'm asleep at the wheel, and I've got to do more while I have the time. So I *hope* other people feel as guilty as I do, because we have failed and now we need to fix it.

The reason I make my programmes is to try and get people to help make a difference, basically. It's why you won't catch me doing cookery shows, because they're not going to save the world, are they?

DO YOU WORRY THE MESSAGES WITHIN YOUR SHOWS ARE DROWNED OUT BY COOKERY AND REALITY SHOWS?

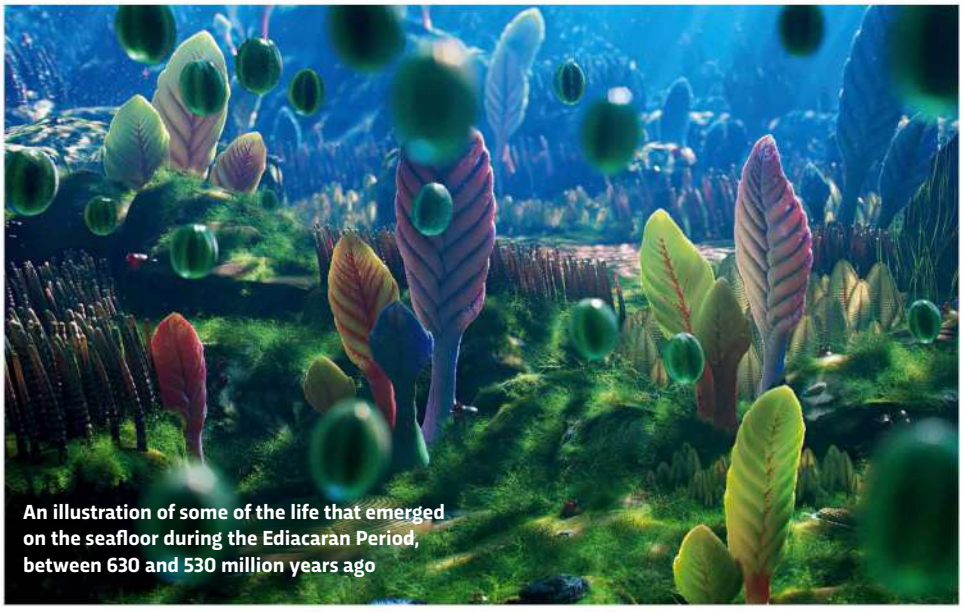
To an extent. But I still want to create a lot of background noise. Would I love to see more direct media attention on climate change? Yes, of course I would. Particularly in the news media – it gets distracted by things I don't consider really newsworthy.

Yet, nobody is going to be surprised by the comments made about the climate breakdown in *Earth*. But our job is to make it a considered part of everyone's lives, so when opportunities arrive – democratically or part of everyday life – they'll make a considered choice.

ARE YOU OPTIMISTIC HUMANITY WILL SURVIVE THIS CRISIS??

Yes and no. I'm very optimistic that, ultimately, we will act to address these issues. But I'm not optimistic about whether we're going to do it with the rapidity that's required to prevent some considerable suffering to our species and others across the planet. Because now is the time act and we're still not doing it.

That's such a motivating force for me, as I see the urgency growing every day. And I have to constantly question what my role in that is.



An illustration of some of the life that emerged on the seafloor during the Ediacaran Period, between 630 and 530 million years ago

BBC STUDIOS X8

The conditions on the volcanic island of Kauai, Hawaii, allow the colocasia, or 'elephant ear' plant, to reach huge sizes. For scale, Chris Packham is about 180cm tall (6ft)

YOU'VE HAD MANY ROLES IN MANY SHOWS OVER THE YEARS. DO YOU THINK THE KIDS WHO WATCHED *THE REALLY WILD SHOW* HAVE FOLLOWED YOU ON YOUR JOURNEY?

It's surprising and flattering to hear that's happened for some people. I've just always tried to make good programmes and deliver good, comprehensible science. Even *The Really Wild Show* had some complex behavioural physiological and ecological ideas in it!

I'm very pleased to have communicated science for as long as I have. Hopefully I can keep on doing it because there's always something new! We've done about 19 series of *Springwatch* and you could ask, "Haven't you run out of things to say about blue tits?" Well, no! There's always something out there that's new!

WHICH ONE ARE YOU MOST PROUD OF?

I'm not proud of anything. I'm very self-critical, so I don't tend to perceive anything that I do as a success in the sense that other people might. When I see that in others, I see a sense of complacency. And there's no time for complacency in my life.

For instance, last night, I was creating an art piece and only finished at 1am. And then got up early to review it and think of ways I can do better. So I've cut it up and tonight I'll have another go. Winning is not giving up, not about ever achieving anything. That's my mantra.

Now, I'm not saying I'm personally important – let's be clear about that. But people do come up to me and say things like, "I saw *The Really Wild Show* and it got me working in conservation!" That's positive, but it's not *personal*. It's not just me who makes the programmes – *Earth* had a *lot* of people behind it!

I think that I've always felt uncomfortable that, as a presenter, I get a disproportionate amount of attention: my job really is quite simple. I have to be the human focus of all of that effort, all of that endeavour – and I've got to project that through that camera lens and out to the public. I feel an enormous sense of responsibility to do that because I'm really there just representing all of those people that come together to make it.

But I never watch myself on TV – it feels uncomfortable!

COME ON. BY PRESENTING ALL THOSE SHOWS, SURELY THAT COUNTS AS MAKING A DIFFERENCE PERSONALLY?

Well, I hope so. I was involved in the show *Inside Our Autistic Minds*, which some people said was good public service broadcasting.

We're at a time where there's an enormous mental health crisis. Now, neurodiversity isn't a mental health issue, but it's certainly a condition that can generate significant mental health issues. And it's only by creating a wider understanding of these issues that I think we'll improve conditions for neurodiverse people.

I had a really rubbish time for about half my life due to being undiagnosed with autism – and for the condition not being really understood. I don't want young people to go through what I went through. So that's why I made that show.

However, ultimately it wasn't personal. It was a BBC show and hats off to all the makers involved!

FIVE TIMES THE EARTH ALMOST DIED

Throughout its long history, Earth and the life on it have come perilously close to total destruction. Here are the narrow misses...

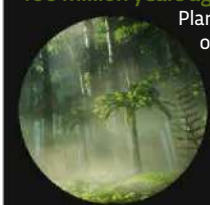
3.2 billion years ago: Asteroid bombardment

Earth is peppered by asteroids, some as big as 60km (40 miles) in diameter – four times the size of the one that killed the dinosaurs. It's thought these asteroids may have helped trigger the planet's plate tectonics.

800 million years ago: Deep freeze I

Earth's supercontinent Rodinia rips apart, sucking carbon dioxide from the atmosphere. As a result, temperatures drop to -70°C worldwide for 50 million years, with ice reaching the equator.

400 million years ago: Deep freeze II

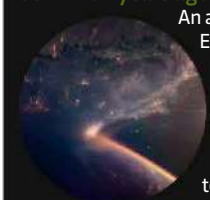


Plant life becomes a victim of its own success, its rapid spread reducing atmospheric carbon dioxide levels, plummeting Earth's temperature once more.

252 million years ago: Inferno

Massive volcanic eruptions lasting 2 million years create lava fields the size of Australia. Around 90 per cent of life on Earth dies.

66 million years ago: Chicxulub impact



An asteroid the size of Mount Everest crashes into Earth, wiping out non-avian dinosaurs. 300bn tonnes of sulphur are blasted into the sky, plunging the planet into darkness and dropping global temperatures by 20°C.

34 million years ago: Icehouse Earth

For reasons still unclear, carbon dioxide levels plummet once again, wiping out primates in the northerly continents of North America and Europe.

COMMENT

THE HUNT FOR INVISIBLE PARTICLES IS OPENING A NEW SCIENTIFIC FRONTIER

The link between theory and experiment is opening a window on to the next iteration of physics

No one has ever seen a Higgs boson. In fact, of all the particles in the Standard Model of Particle Physics arguably only the photon (a particle of light) is, in any sense, visible. All the others – quarks, electrons, mu and tau leptons, neutrinos, gluons, and W and Z bosons – are effectively invisible.

As for the Higgs boson, even indirectly inferring its existence took a 40-year search with the most complex machine ever built. Its discovery in 2012 at the Large Hadron Collider (LHC) was considered one of the most important advances of modern physics and a huge success of the Standard Model.

Using a combination of data from ATLAS and CMS, the LHC's two biggest detectors, the Higgs detection confirmed our picture of how fundamental particles (such as quarks and electrons) acquired the properties we measure today, and how the forces of nature arranged themselves in the early Universe.

Now that we have the Higgs, researchers at the LHC have been hoping to use it to better understand the Standard Model itself or, ideally, find a hint of 'new physics' that would indicate what kind of theory might replace it. But how do we study a particle we can't see? What are we really looking at? The answers are complicated, but they touch on something much deeper: the entanglement of theoretical models and experimental data.

One problem is that the Higgs doesn't just exist naturally in the wild, waiting to be captured. If you want a Higgs boson, you have to create one. Fortunately, subatomic particles can be coaxed to transmute into one another, given the right conditions, based on a complex web of interactions described in the Standard Model. At the LHC, physicists smash protons together at high speeds, knowing that more energy means more massive particles can appear. Dial the energy up high enough and some of those will be Higgs bosons.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

Production is only half the battle, though, because once a Higgs is born, it has a lifetime of less than a billionth of a trillionth of a second. So even if you do manage to create one, it'll decay into other particles (with rates depending on Standard Model rules) so quickly that even the LHC's detectors can't see it happen.

Standard Model parameters come into both sides of this process: the production of the Higgs, and the way it decays. The connection between theory (the Standard Model) and experiment (collision and detection) is iterative: the theory tells us what to expect from the experiment, and the experiment helps us refine, or reject, the theory. Without the experiment, we couldn't test the theory, but without a theory, the data would mean nothing.

Our first experimental glimpse of the Higgs came from two distinct signatures. One was pairs of high-energy photons, each carrying off half the energy of the (suddenly decayed) Higgs particle. The other was even less direct: the Higgs decayed into other unstable particles that then decayed into less-unstable particles, which could survive long enough to be detected by the LHC's ATLAS and CMS detectors.

Even these longer-lasting particles aren't seen directly, but instead trigger specialised detectors, which count the number and energy of the particles they detect. At every point, experimentalists must contend with 'backgrounds' – detector triggers due to a confusing shower of particles unrelated to the ones they're looking for.

In May, LHC scientists announced that they had seen, for the first time, evidence of the Higgs decaying into a photon and a Z boson (a particle that carries the weak nuclear force). Intriguingly, signs of this rare decay were seen about twice as often as predicted, which could indicate that the web of interactions described in the Standard Model might need to be revised to include some new particles.

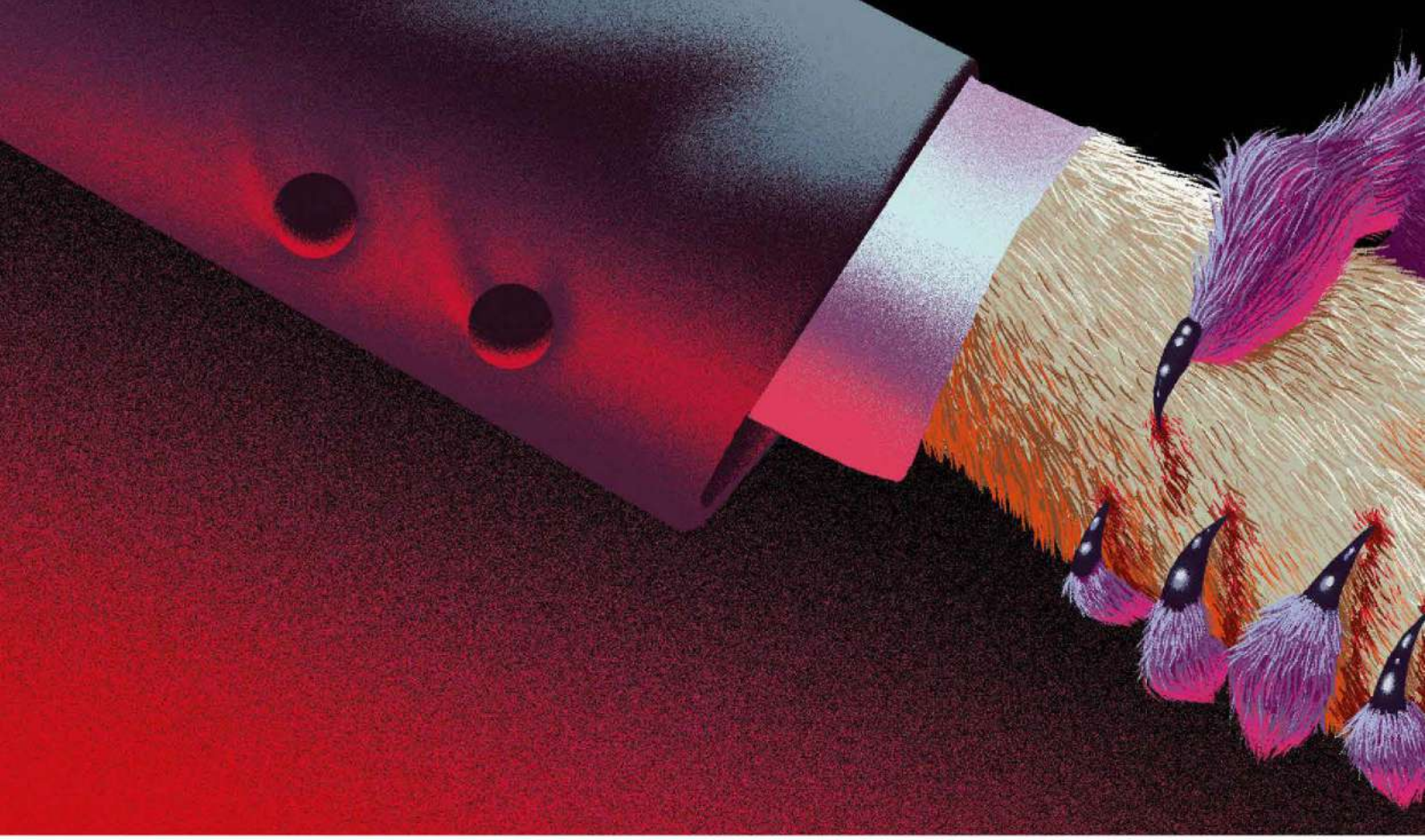
As we dig deeper into the workings of fundamental physics, we'll continue to find ourselves relying on methods that seem to be increasingly removed from directly 'seeing' what's happening.

This means finding new ways to tease a tiny effect out of a background of complicated noise, including (as in the rare decay measurement) using methods such as machine learning to help.

The ancient Greek polymath Archimedes once said that with a lever long enough, he could move the world. The LHC is perhaps the longest lever we've ever built, linking together an increasingly complex set of experimental and theoretical tools to uncover the fundamental workings of our Universe.

"The Higgs doesn't just exist naturally in the wild waiting to be captured"

ILLUSTRATION: MATT HOLLAND



COMMENT

YOU'RE HARDWIRED TO TRUST CONFIDENT VOICES... EVEN WHEN THEY'RE WRONG

Human evolution has led to us naturally believing statements that are delivered in a more assured manner

A lie is halfway around the world before the truth has got its boots on. It's a well-known phrase. But a more accurate version would be: a confidently told lie is halfway around the world before the truth has got its boots on.

Lies can travel so much quicker because we humans are far more likely to accept and believe information delivered confidently by a confident person, or some other source, using confident language. And as the modern world has repeatedly shown us, this regularly leads to undesirable outcomes.

Humans trusting confident people over those who are more uncertain is an established phenomenon. The 'confidence heuristic' states that when two (or more) people are trying to make a decision but each person knows different things, confidently expressed arguments are perceived as conveying better information, which determines the decision.

Why would this tendency come about? Well, humans are ultrasocial and during our evolutionary development, most of our information concerning the world came from our tribe, in other words: the people around us. So, if ancient humans heard someone confidently declare: "There's a predator coming," instinctively believing what that person had to say was a valuable survival trait.

Humans are also hierarchical. We have social status and our communities often have leaders who tend to be confident sorts. In early societies, which faced danger at every turn, a tendency to unthinkingly believe the confident leader and do what they said, was another useful survival trait.

On a more personal level, much of our thinking about, and perception of, others tends towards the egocentric; we relate what they do and say to our own experiences, because that's typically what our brain has to work with. If, on the occasions that we're confident, it's for good reason, we therefore assume that when someone else is being confident, they must have good reason too.

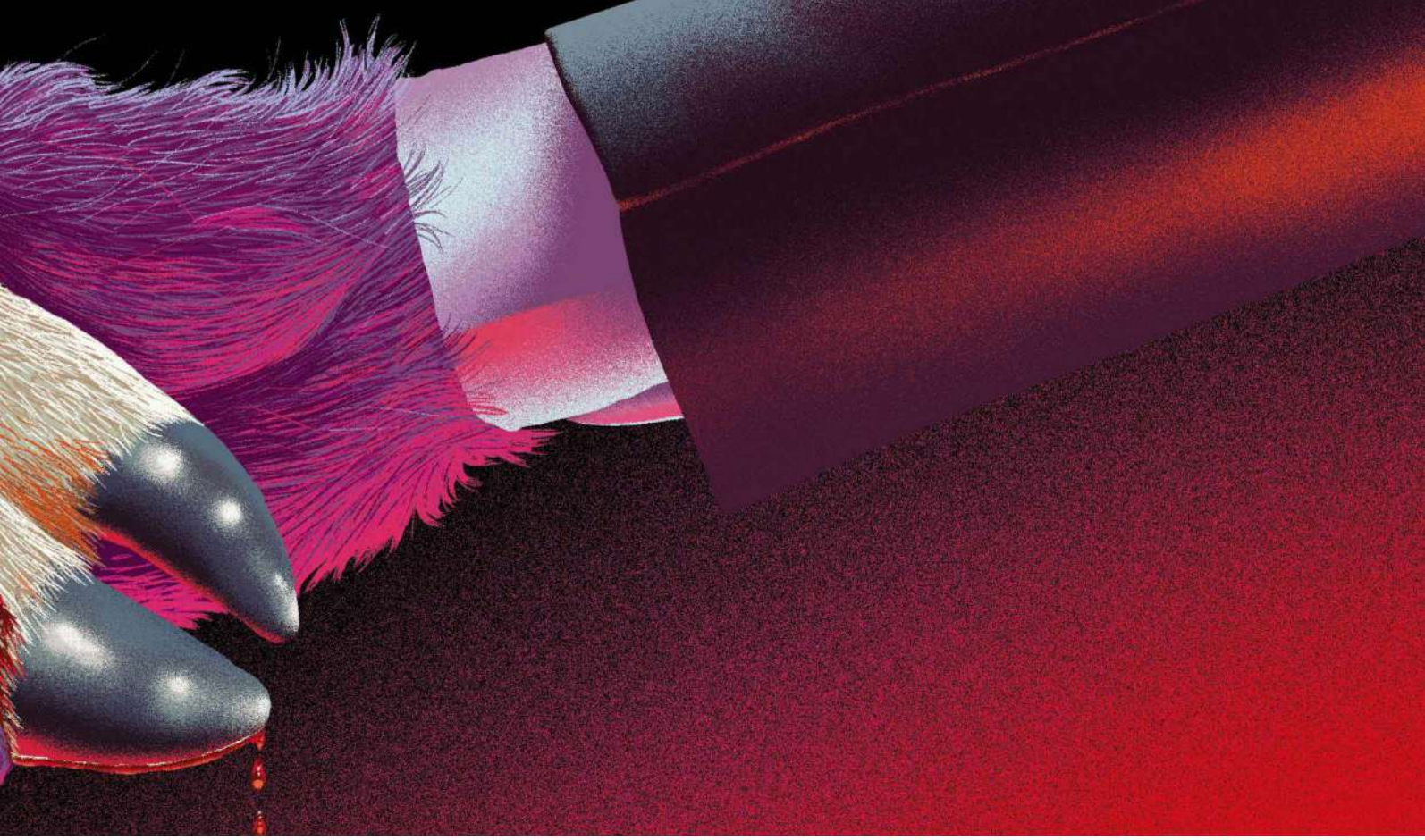
There are caveats, however, such as credibility. A megaphone-wielding street preacher, bellowing that the world is about to end, may seem more confident than a friend recommending a restaurant, but the latter will carry much more weight.

Similarly, the manner of communication affects the assessment of confidence. Someone may be very confident in their claims/ideas, but if they deliver them hurriedly, or quietly, we're less likely to recognise this confidence. Slow, clear speech is associated with confidence.

So, there are many reasons why we trust confident people. Now, here are some why we shouldn't.

Confidently delivered information may be more persuasive, but that doesn't mean it's correct, even if the confident person genuinely believes it is.

ILLUSTRATION: BERNARD LEONARDO



“Higher intelligence makes you more aware of what you don’t know”

Even that’s not certain, because humans have long been able to deceive. It’s easy enough for certain people to feign confidence convincingly, even if they’re conveying the most meaningless guff. But ‘wrong confidence’ need not mean deceit. For one thing, confidence is linked to intelligence. We’ve all met someone who will happily lecture others on how the world works, despite being wrong about literally everything.

It’s the Dunning-Kruger effect, where people with low ability/experience/knowledge about something often significantly overestimate their abilities/expertise regarding it. They do this because the ability to recognise your intellectual limits requires sufficient intelligence. Lacking that, you won’t question your (limited) understanding, so can spout laughable nonsense with the utmost confidence.

Meanwhile, higher intelligence makes you more aware of what you don’t know, leading to things like imposter syndrome and diminishing confidence. Suddenly, mistrust of experts and rejections of their conclusions makes more sense.

Then again, someone with perfectly normal intelligence could still end up excessively confident, especially if they have a very privileged existence. An affluent, pampered life – particularly during childhood – can mean never suffering the consequences of being wrong. Such a person could end up believing they aren’t wrong… ever. Their brain has never had the opportunity to recognise this occurrence. So, they’ll deliver every utterance with unshakeable confidence, purely because it’s them saying it.

This happens later in life too. As stated, much of what we understand about the world, and ourselves, comes via information from other people. So, if you achieve success in your field legitimately, and your confidence is therefore ‘valid’, you can still end up surrounded by those who agree with and support you – people who validate everything you say or think.

Big celebrities, surrounded by entire networks of people dedicated to serving them and keeping them happy, regularly develop massive egos, which often leads to them confidently, and publicly, stating the most ridiculous things.

This is important. We live in a highly interconnected, increasingly complex society, where innumerable people and worldviews end up overlapping constantly. So, someone who is objectively, unquestionably wrong, but still unshakeably confident can end up convincing many others that they’re right.

Often by providing easy answers for complex modern issues, particularly ones that ‘confirm’ pre-existing worldviews or prejudices. This makes them more high-profile, thus more legitimate and convincing, so they gain more support and followers, and the cycle continues.

Left unchecked, it can lead to individuals with no abilities or redeeming traits beyond unshakeable confidence being put in charge of entire countries. And that won’t end well for anyone. You can be confident in that conclusion.

DR DEAN BURNETT

Neuroscientist Dean explores the nature of dreaming in his latest book Emotional Ignorance *(£14.99, Guardian Faber).*

COMMENT

THE VAGINA'S HUGE MEDICAL POTENTIAL IS GOING UNTAPPED. BUT NOT FOR MUCH LONGER

Scientists are beginning to investigate the organ's potential healthcare applications... and there's a lot of them

In medicine, conversations about vaginas have been remarkably narrow. Usually, they only occur after the vaginal delivery of a child, when healthcare professionals access the cervix for screening or when the body of the uterus is examined for other medical procedures. And when vaginal health is reviewed, it's usually focused on infections such as sexually transmitted diseases and cancerous lesions.

But the vagina is a dynamic organ. Take, for example, the many biological changes that occur throughout the menstrual cycle. It also has its own microenvironment, a carefully balanced microbiome containing billions of bacteria, and we're only just beginning to understand the role this plays in vaginal, reproductive and public health.

The vagina's potential as a route for diagnostics and therapeutics has largely been ignored. But now, scientists, doctors and pharmaceutical companies have started to look at the organ in a new way.

"Menstrual blood collected in the vagina has great potential as a diagnostic tool"

DR MICHELLE GRIFFIN

Michelle is the director of MFG Health Consulting, as well as a women's health expert and strategy advisor in women's health tech.

As it can be easily self-accessed, the vagina allows for intervention anytime, anywhere. There's no need for hospital visits or invasive procedures. This gives women the benefit of near-complete independence and continuous monitoring or treatment. And new developments also mean the vagina could provide an easy route for delivering medication.

Already, local medication such as topical oestrogen for genitourinary symptoms of menopause is given in the form of cream, a pessary (a tablet that can be inserted using an applicator) or a ring inserted directly into the vagina – usually by the patient. Similarly, women going through assisted reproductive treatment, or trying to conceive following a miscarriage, may be prescribed the hormone progesterone as a vaginal pessary.

One of the current problems with vaginally inserted medications is they often result in drug leakage and increased discharge. But the company Calla Lily has developed a new leak-free vaginal drug-delivery platform. It's simple to use (essential when patients have to administer medications themselves) and also helps to alleviate dosage anxiety and other stresses.

There's also a combined contraceptive vaginal ring, which releases a continuous dose of oestrogen and progestogen into the bloodstream via the vagina. Many more medications could be delivered in the same way.

The dense blood supply potentially enables systemic medications to be delivered via the vagina, which, unlike oral tablets, has the advantage of avoiding the gut. This prevents any digestive side effects such as nausea, vomiting and diarrhoea. It also, bypasses the first metabolism in the gut and liver, thus avoiding a reduction in drug concentration. Developments like this have huge potential, and could be the best way to deliver medication to the vagina and nearby organs.

But it doesn't stop there. Menstrual blood collected in the vagina has great potential as a diagnostic tool. Research is currently looking at how to use menstrual blood to detect diseases such as endometriosis, which affects 10 per cent of women. It's a chronic condition, causing significant pain and infertility, and currently takes an average of seven years to diagnose.

The vagina is also significantly affected by infections. One of the most common is thrush, with as many as 75 per cent of women developing it at least once in their lives and over 138 million women worldwide suffering from recurrent thrush.

This highlights the need for the development of a solution that enables women to check, monitor, diagnose and treat any vaginal infections or disruptions in the microbiome that may occur.

Critically, more research is needed to understand the biology of the vagina, including the microbiome and the factors affecting it. This will enable us to better grasp the potential effects of diagnostics, therapeutics and care products (tampons, moisturisers and washes) on vaginal irritation, sensitisation, microbiology and Toxic Shock Syndrome, which is a rare but life-threatening bacterial infection often associated with the use of tampons and other vaginal products.

There can also be psychological and/or social barriers to using vaginal products that involve self-examination and insertion. Of course, like any product, there needs to be a high level of personal acceptability. However, this can be shaped by cultural sensitivities.

In Europe, for instance, the use of non-applicator tampons is far higher than in the US. If the medical potential of the vagina is to be fully realised, it's critical for women to be deeply involved in the development of future products, to encourage a societal shift and recognise its importance and potential.

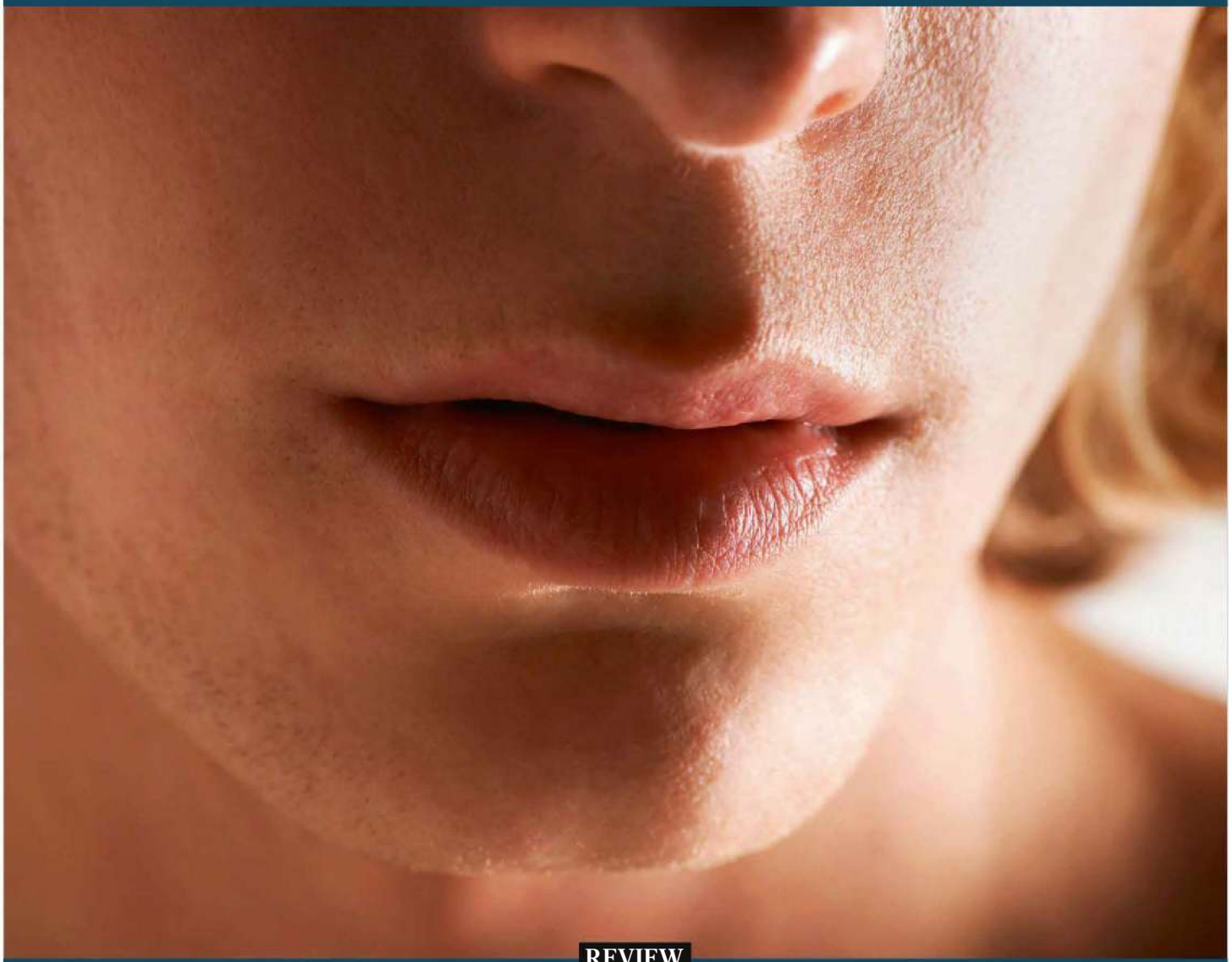
That's a challenge that must be overcome, as the future of the vagina is one of immense potential for diagnostics, therapeutics and self-care.

ILLUSTRATION: CHIARA XIE

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

Mewing | Signs of life | Older dads



REVIEW

MEWING: CAN THE TIKTOK TREND GIVE YOU THE JAWLINE OF A MODEL?

Its supporters claim a simple tongue exercise can not only reshape your jaw and help you sleep, but can even improve your teeth. Here's what the experts say...

"It's generally accepted that human jaws are getting smaller and have been since the dawn of agriculture"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Lose your double chin! Straighten your teeth! Get a jawline so well-defined you could open a bottle of beer on it! These are just a few of the supposed benefits of 'mewing', an odd but popular practice of DIY facial reconstruction – no cosmetic surgery required.

Originally conceived by a controversial orthodontist, the technique has become a viral beauty trend on social media platforms.

Mewing tutorials on TikTok, popularised by the supermodel Bella Hadid, have millions of views and hundreds of thousands of likes, bolstered by intriguing before-and-after photos.

Tempted? We think you look lovely just the way you are. But just in case, we looked for evidence that mewing actually works… and not just on TikTok.

WHAT IS MEWING?

It's the process of shoving your tongue to the roof of your mouth and leaving it there in the hope that it'll affect the 'chiselledness' of your jawline. Proponents believe that if you keep your tongue raised for prolonged periods, it can reshape and restructure your jaw. And not only that: mewers believe it could also help reduce jaw pain and sleep apnea, help with snoring and treat occlusions or overlapping teeth.

WHERE DID IT COME FROM?

Mewing takes its name from Dr John Mew, a British orthodontist who first popularised the practice in the 1970s. His son Mike, also an orthodontist, promotes the practice today and is often credited with driving its popularity on social media platforms.

John Mew incorporated mewing in his so-called orthotropics practice, which includes a number of facial and oral posture techniques designed to widen and strengthen people's jaws.

WHAT'S THE THEORY BEHIND MEWING?

It's generally accepted that human jaws are getting smaller and have been since the dawn of agriculture. Food is easier to consume. Pillows are nice and soft. Our mouths don't get the workouts they once did.

The Mews believe that smaller jaws mean crowded, crooked teeth and less volume in our mouths. Mewing is designed to reverse this effect and, as a bonus, it makes you look more like a model in photographs.

SO, DOES IT WORK?

Well, it's complicated. Raise your tongue to the roof of your mouth and you may notice a difference in your profile as your tongue pulls up the tissue at the base of your mouth and directly under your chin. Can you keep it there, though? And would that make any kind of long-term difference?

"To date, there is a lack of rigorous scientific studies that specifically investigate the effectiveness of mewing," says dentist Dr Kam Aulak, whose work includes cosmetic dentistry at Newhall Medical and Dental Aesthetics.

"Many dental professionals and orthodontists have expressed scepticism. Critics argue that facial structure and development are primarily determined by genetics, and altering these factors through tongue posture alone is unlikely to yield significant changes."

There is some research linking 'oral posture' to jaw development, but Aulak (who also runs the Skin Culturist) cautions that it's not geared towards the claims made by mewing enthusiasts.

"The limited research available on tongue posture and its impact on oral health primarily focuses on its role in orofacial myofunctional therapy, which is a broader field dedicated to correcting orofacial muscle imbalances," he says.

It should also be noted that both John and Mike Mew are controversial figures. At the time of writing, Mike Mew was awaiting the result of a misconduct hearing held by the UK's General Dental Council.

His father stepped down as a dentist after having his licence revoked by the same body for a controversial series of advertisements.

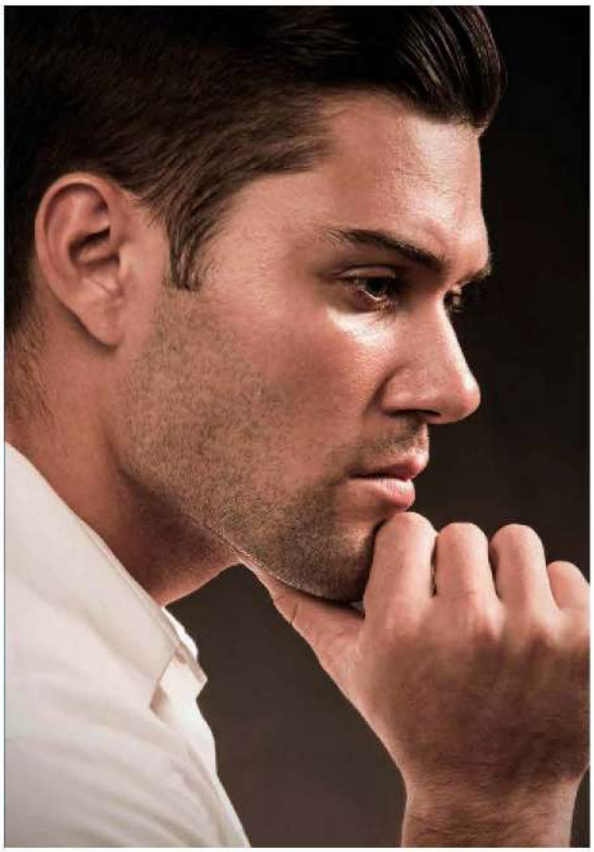
CAN YOU HURT YOURSELF DOING IT?

If your aim is simply to look a little more like a henchman from a 1980s action movie, then poking your tongue to the top of your mouth is unlikely to cause any distress or injury. But the risk is not zero, Aulak says.

Applying too much force could lead to straining the muscles in your jaw, neck or face. "Mewing may also affect individuals who already have braces or orthodontic treatments in progress," he says. →

ALAMY

LEFT Human jaws and oral cavities have been shrinking for thousands of years



ABOVE Experts think genetics are the primary factor that determine a person's facial structure and development

→ Orthodontists have also expressed concern that the trend for mewing on social media could lead people away from traditional and better-understood orthogenic procedures.

ARE THERE ANY WAYS TO TONE YOUR JAWLINE THAT ACTUALLY WORK?

There are a number of surgical and non-surgical procedures that promise to reshape your jawline, but all come with risks and small print. These cosmetic treatments and tweakments range from fat removal under the chin to dermal fillers that pad out your jawline.

"Cryotherapy and muscle stimulation [also] give the effect of tighter, plumper skin around the neck and lower face," says Gemma Clarke of wellness and aesthetics company Gelida, "as well as sculpting the muscles of the face to give a lifted, more youthful appearance."

Cryotherapy uses the cold to stimulate shock in the skin, which Clarke says results in tighter skin over the neck, jowls and face. Muscle stimulation, meanwhile, is a kind of workout for under-utilised facial muscles, which are stimulated electronically. "No fillers or surgery needed," she says.

by **IAN TAYLOR**

Ian is a freelance science writer and the former deputy editor of BBC Science Focus magazine.

ANALYSIS

SIGNS OF LIFE: COULD A SUPERNOVA BE A SIGNAL?

Astronomers think aliens could use supernova explosions to inform us of their presence

Imagine you're an alien on a distant planet and you're desperate to let everyone know you're there. Instead of howling aimlessly into the void, how can you give yourself the best chance of being heard? According to new research, extraterrestrial civilisations could piggyback a signal onto one the brightest beacons in the known Universe: a supernova.

These cataclysmic explosions detonate as the biggest stars die. For a time they shine as brightly as 10 billion Suns and release as much energy as the Sun will emit in its entire 10-billion-year lifetime. When a supernova goes off, astronomers sit up and take notice.

In May this year, astronomers erupted in a flurry of excitement when they spotted the supernova SN 2023ixf detonate in the Pinwheel Galaxy (also known as M101). "It was the closest supernova in a decade," says James Davenport, an assistant professor at the University of Washington. It was bright enough to see with amateur telescopes, even though M101 is 21 million light-years away.

A team led by Davenport has examined the possibility that an alien civilisation may choose to flag us down by coordinating their message with the light from this supernova in a ploy known as 'signal synchronisation'. "They shout, 'we are here' in a conspicuous way," Davenport says. That civilisation will know astronomers from other inhabited worlds, like ours, will probably be looking in the direction of the supernova, making the chances of that message being spotted far higher.

So where exactly do we look? The search area is defined by an oval-shaped region within the Milky Way called the 'SETI ellipsoid' (SETI is an acronym for the search for extraterrestrial intelligence). The aliens in question have to be nearer to the supernova than us in order for them to be able to see its light first and then have time to quickly send on an accompanying message that will arrive on Earth close to when we see the supernova. "It's the same math[s] that goes into figuring out echoes," Davenport says.

It's civilisations on the perimeter of the ellipsoid that we're most interested in. We'd have already missed the signals from those stars far inside

ALAMY, GETTY IMAGES

“That civilisation will know that astronomers from other inhabited worlds, like ours, will probably be looking in the direction of the supernova”

BBC iPLAYER
Watch *Universe* to discover more about Sagittarius A*, the black hole at the centre of the Milky Way – available now on BBC iPlayer
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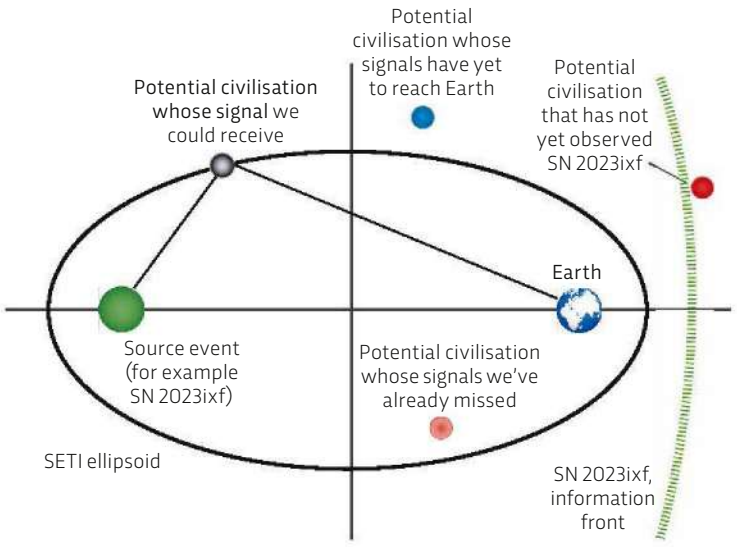
it and stars outside may have seen the supernova, but any synchronised message hasn’t had time to reach Earth yet.

Working out which stars are in the right place has only recently become possible. “Missions such as Gaia have given us really precise locations of stars,” Davenport says. “There are around 100 stars currently in the sweet spot.” Armed with that knowledge, Davenport pointed the Allen Telescope Array in California at each of them over the course of a single weekend.

ABOVE Supernova events are bright enough to send light across a very wide area and be seen by anyone that may be living within it

Did he hear anything? Not yet, but all is not lost. “We’re going to revisit them a few times over the next couple of months because there’s some uncertainty over when the signals would arrive,” Davenport says.

That uncertainty stems from how quickly after the supernovae the alien civilisation would send their message. “Would they have to go to alien Congress and ask permission to send it?” Davenport asks. There could be a few weeks’ delay. Revisiting those stars also opens the door to being able to detect faint signals that slowly change, rather than taking →


Potential civilisation whose signals have yet to reach Earth
Potential civilisation whose signal we could receive
Potential civilisation that has not yet observed SN 2023ixf
Earth
Source event (for example SN 2023ixf)
Potential civilisation whose signals we've already missed
SETI ellipsoid
SN 2023ixf, information front

ABOVE A civilisation in the right place could synchronise a signal with a noticeable event, such as a supernova like SN 2023ixf, which could be received on Earth

→ just one snatched five minute glimpse and saying nothing is there. "They could be sending a wave of information," Davenport says.

The SETI ellipsoid is also constantly shifting to incorporate new stars as the passage of time allows both the light from the supernova and the relayed signals to travel further. So we could be scanning stars on the perimeter of the ellipsoid for years to come. Plus, SN 2023ixf is just one supernova. Every nearby supernova has its own ellipsoid to comb through.

Davenport's work predates this most recent explosion – he originally focussed on the supernova SN 1987A. "Even though it happened nearly 40 years ago there are still stars where the [synchronised] signal would only just be reaching us."

How does Davenport rate the chances of success? "They're low on any given day," he says. "My guess is that it could take us a thousand years, but that's okay." A millennium may sound a long time, but humans routinely do things on such timescales. The University of Bologna, Europe's oldest, has been teaching students ceaselessly since 1088, for example.

"You have to start somewhere," Davenport says. "It's about leaving a legacy of data and of methodology." Every school student today is taught ancient ideas like Pythagoras's Theorem, which is more than 2,500 years old. The best things take time and good things come to those who wait. One day measurements of a star on the edge of a supernova SETI ellipsoid might just go down in history as one of the most important observations ever made.

by **COLIN STUART** *(@skyponderer)*

Colin is an award-winning astronomy writer and speaker.

COMMENT

OLDER DADS: ARE YOU EVER TOO OLD TO BECOME A FATHER?

What are the risks and rewards, to you and your children, of becoming a father late in life?

We're all aware of the limits that menopause places on female fertility. But we're perhaps less concerned with what happens to male fertility past middle age. With movie stars Al Pacino and Robert De Niro welcoming children at 83 and 79, respectively, it's easy to assume that age is no barrier to becoming a father (the official record stands at 92). But is it really that straightforward?

The age that people become parents has been rising since the mid-1970s and is now at an all-time high, with the average age for fathers being 34, compared to 31 for mothers. As male parents are most often dependent on female partners – usually of a similar age – to conceive, this rise applies to men as much as it does to women.

But as fertility specialist Dr Sarah Martins da Silva from the University of Dundee notes, the reasons why parents – of any sex – keep getting older are complicated. "I think there's a bigger political, socioeconomic discussion around that relating to the economy, provision of childcare and people not being so financially stable," she says.

While women have a finite number of eggs in their ovaries, men can continue making sperm indefinitely. Male fertility does drop off with age, but it's more of a "gradual slip", Martins da Silva says, than during female menopause. The drop-off is partly due to lower levels of hormones; testosterone, for example, is thought to decrease by as much as two per cent per year after age 30. Past 40, levels may vary more from person to person, but, on average, they don't continue dropping, according to one large study.

Sperm numbers and quality do slowly decrease with age, however. Sperm quality covers a combination of different factors. For example, sperm cells produced by older men may be poorer swimmers and therefore less likely to reach and fertilise an egg.

Underlying these changes are genetic changes that accumulate during any person's lifetime and that can't be avoided or reversed, no matter how much you try to live a healthy life. The upshot is that while it's still eminently possible for an older man to father a child, it won't necessarily be as straightforward as it would be for a younger man.

GETTY IMAGES

"While women have a finite number of eggs in their ovaries, men can continue making sperm indefinitely"

ABOVE
Robert De Niro (left) and Al Pacino, aged 79 and 83, respectvely, have both recently fathered children

So, can a man become a father at any age? Theoretically, yes, given that it only takes one healthy sperm to fertilise an egg. According to Martins da Silva, there's "no cut-off point" at any stage. "There are people in the press in their 70s and 80s who are fathering children," she says. "And it shouldn't be a particular surprise to us that men are still able to do that, because the biology is completely different [than it is in women]." In many countries, there's also no limit on when a man can access fertility treatment, whereas in the UK, for example, the NHS only routinely offers treatment for women up to age 42.

There are, unfortunately, increased risks for the father and any potential children. A 2020 review looking at the effects of paternal age on miscarriage found that the risk of miscarriage goes up with increasing age, although the effects of female age on pregnancy loss are more pronounced.

For children born to older fathers, there's plenty of evidence to suggest they're at greater risk of a range of health conditions, which may be connected to genetic mutations stacking up as we age. Heart defects are more common and the risk of psychiatric disorders increases in children with older fathers.

Importantly, however, some conditions that are more likely to occur are very rare in the general population, meaning that even when the risk is increased, it remains pretty low.

One risk that many children with older fathers do face, though, is their father dying when they're still young and any impacts that may have. "They tend to do a lot worse in terms of social development, school progress and so on," says Martins da Silva. "But it's often in a situation where there's lots of financial hardship as well."

The rich and famous aren't your typical older fathers. Most of us don't make the kind of money that Pacino and De Niro do, so we can't really relate to the circumstances that they're bringing children into, or the decisions they make about fatherhood. Celebrity-level earnings could help to eliminate the financial impact of losing a parent at a young age, for example.

On the other hand, ageing celebrities becoming fathers might help highlight the issue of male fertility, which is valuable because, as Martins da Silva points out, it's an issue that's given frustratingly little attention. "I think, generally, men and fertility isn't a conversation that happens in sex education in schools, or in life." SF

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a freelance science writer and editor.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

ANALYSIS

AI ART'S CREATIVITY CRISIS

How can we train AIs to create something new, rather than regurgitate old ideas? **p40**

REVIEW

OUTDOOR SPEAKERS

Turn your garden into Glastonbury with one of these wireless speakers **p42**

NEW TECH

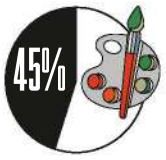
IDEAS WE LIKE

Our pick of this month's greatest new gadgets **p44**

Teenage Engineering's OB-4 speaker is old, new and classy all at the same time **p42**

THE FIRST SIGNIFICANT AI ART GENERATOR CAN BE TRACED BACK TO THE

1970s



THE PERCENTAGE OF ARTISTS WHO HAVE USED AI GENERATORS TO INSPIRE THEIR WORK

10,000,000

THE NUMBER OF DAILY USERS OF THE AI IMAGE GENERATOR STABLE DIFFUSION DURING ITS PEAK IN 2022

ANALYSIS

AI art's hidden echo chamber is about to implode

Artificial intelligence creates millions of images a day, flooding the internet. But what happens when it starts to train on its own data?

In the past year, art created by artificial intelligence (AI) has gone from being the subject of research papers to emerging as a niche fad, all the way through to becoming an internet-dominating tool producing millions of images a day.

To get to this point of ubiquity, however, all the AI models had to be trained. And their training involves a hugely comprehensive deep-dive of the internet, in which they scan billions of images along with the images' corresponding descriptive texts.

Not only does that raise some major ethical questions around copyright, it also begs one question for the future: what happens when the internet becomes flooded with images made by artificial intelligence?

As these models continue to train by scouring the internet, they will undoubtedly be trained on images they first created. Does that cause some sort of self-perpetuating loop of weirder and weirder images, or will nothing actually change?

THE LOSS OF CREATIVITY

"AI will eventually start training on its own work – it's expected to happen. That will essentially lead to stagnation in creativity. They train on what is already on the internet, so they will copy what is popular out there," says Ahmed Elgammal, a professor of computer science at Rutgers University, in New Jersey.

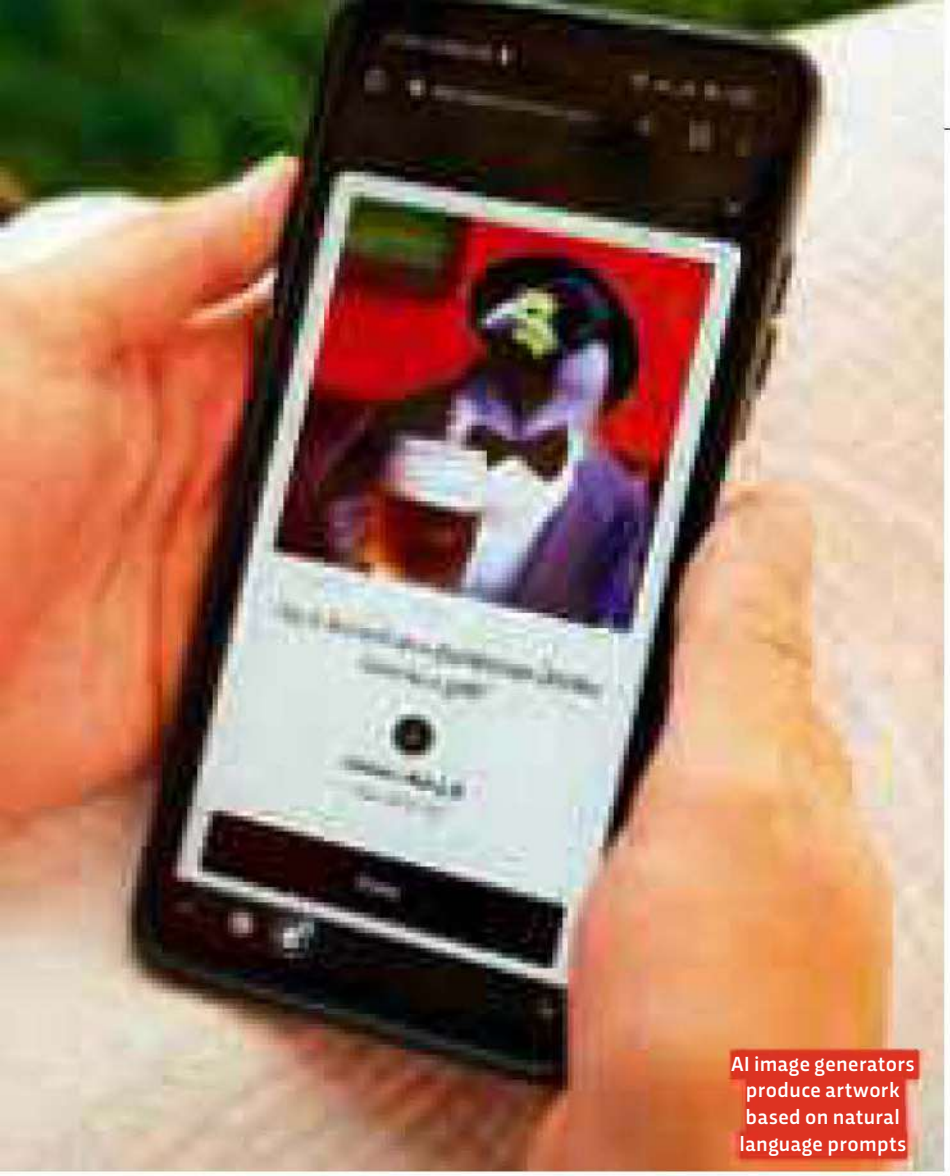
"If you get into the cycle of feeding AI what's on the internet, which right now is mostly AI, that'll lead to a stagnation where it's looking at the same thing, the same art style, over and over again."

While it's easy to picture a future where AI starts pushing out morphed art, driven by repeated training on its own images, it's far more likely that this will simply further promote what it's already creating.

"Basically, AIs will converge on anything that's popular. More of what's popular will see them stick to certain art styles that are popular on the internet and the AIs will become biased to that. Whatever is dominant right now, that's what the AI models will learn to push even more."

Seemingly simple prompts can lead to surprising results. This image came from 'city panorama with penguins'

The prompt 'flight attendant' more often results in images of women



AI image generators produce artwork based on natural language prompts

This creates two problems. Firstly, it'll cause the art that AI is making to stick to a limited set of styles, leading to generations of art to that look very similar and lack the imagination most people aim to get out of AI generators.

The second problem is that if AI art begins to be recycled back into itself, it'll be ingesting any biases that are common in its own creations. This could mean everything from unrealistic body types to inaccurate hands, and an over-reliance on genders in certain roles.

"If there are biases in the images being produced, such as people searching for specific beauty types and aesthetics, these are going to end up being recycled back into the AI," says Elgammal.

"The beauty of human creativity is being able to like or dislike anything, it doesn't just have to be what the most popular option is right now. If these models get stuck in a feedback loop, they take that sense of individuality away."

Ever since OpenAI released Dall-E 2, the generator that kicked off this recent movement, the consequences of these models being trained on material containing such biases and stereotypes have been obvious for all to see.

Dall-E 2 had the tendency to offer up images containing men when prompted for images of builders, while prompts for images of flight attendants would mostly result in pictures of women.

Similarly, westernised depictions dominate the results when the prompts contain unspecific terms related to religious ceremonies or race.

As most AI image generators are trained in the same way, they have all assimilated these biases and produced images containing them, which, when returned back into the system would further promote them.

This isn't just a problem for AI image generators. All forms of AI trained on material from the internet have suffered from the human biases they've encountered. Chatbots like ChatGPT and Google's Bard have been known to provide information based on conspiracies, racist humour or biased statements around gender.

The problem arises in any AI platform that creates large amounts of content for the internet and trains itself on content it finds there, creating an endless feedback loop.

WHAT'S THE SOLUTION?

There's no way to know if this is what's actually happening, or if it ever will. But Elgammal sees it as a likely future, as AI models continue to train themselves on the wealth of free images available online. So what's the solution?

The most obvious option is to move away from the current training formula.

"I think we need to rethink how this is done. Instead of training these models on huge pools of data, people should be taking their own artwork, or work they have permission to use and training their own models based on these images," says Elgammal.

"By doing this, you're getting something that's completely unique to you, something that you simply can't achieve with these massive models."

"IF THERE ARE BIASES IN THE IMAGES BEING PRODUCED... THESE ARE GOING TO END UP BEING RECYCLED BACK INTO THE AI"

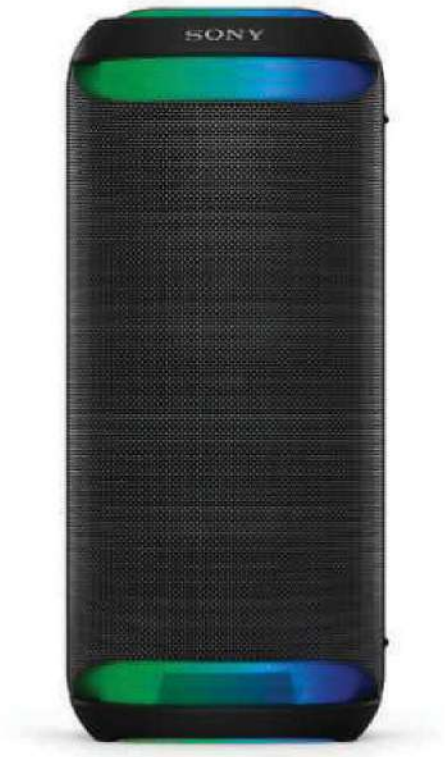
Of course, this only really applies to artists looking to get the most unique results out of their generators. For the average user, a large, fully trained model will be the option worth going for.

In future, these models could find new ways to train, developing new art styles and even an understanding of how an image would operate in three-dimensional space. There is, however, just as much of a risk of stagnation with AI art simply going in circles, learning biases and developing a focus on a singular style of art.

ALAMY X2, SHUTTERSTOCK IMAGES

Five of the best outdoor speakers

A good outdoor speaker needs to be portable, offer great audio and be able to stand up to all types of weather. The *BBC Science Focus* team picks their faves



Sony SRS-XV800

Sony.co.uk, £599

With a price tag of £599, Sony's high-tech SRS-XV800 wireless party speaker is a fair bit more expensive than most portable Bluetooth speakers on the market. However, for paying all those extra pounds, you get an unquestionably premium and multipurpose device that even keen audiophiles are unlikely to find fault in.

Built for large house parties rather than quaint picnics, it's a speaker capable of playing crisp and clear music in a plethora of genres at staggeringly high volumes. Plus, with 25 hours of battery life, it can keep the party going literally all day long (don't blame us for your official noise complaint).

The one drawback? Unless you've been hitting the gym, it has limited portability. Weighing 20kg, it's a real chore to carry, and the small built-in wheels at the base of the speaker are only useful when you're travelling over flat terrain.

Worryingly powerful, ruthlessly high-performing, but awkward with stairs, consider Sony's SRS-XV800 the Dalek of Bluetooth speaker world.

Sonos Move

Sonos.com, £399

The Sonos Move is one of those speakers that just gets on with the job. The subtle, no-fuss design and sleek profile allows it to blend quietly into the background of your room, integrating itself with everyday life and enhancing your audio experience – you almost forget it's there.

But when it's time to crank up the volume, the Move delivers in spades. Thanks to its two digital amplifiers, tweeter and mid-woofer, it produces crystal clear highs and hearty basses.

An ergonomic handle groove built into the back of the speaker ensures it's well-balanced whenever you find yourself having to move it, while Trueplay ensures it's acoustically balanced. A rather nifty feature, the Trueplay system does this by measuring how sound is reflected off walls, furnishings and other surfaces, then optimises the audio based on these acoustics.

Better still, you don't need to calibrate the speaker yourself – it does it automatically when you move locations.

Minirig 3

Minirigs.co.uk, £139.96

The Minirig-3 is scarily good. We mean that literally: after taking it out of the box and wondering how loud it could go, we started backing off the volume button having reached just 40 per cent.

It's almost silly, but then it makes sense when you understand the story behind the product. The Bristol-based masterminds started life setting up sound stages for gigs and parties, and that's essentially what you're getting here: a party sound system that fits in the palm of your hand.

It's not just brute power though. There's clarity and subtlety here too. It handles hip-hop like Little Simz's *Gorilla* with grace, balancing heavy bass without distorting the vocals in the mid-range. Meanwhile, Turnstile's thrashing guitars on *Holiday* never drown out the cymbals or the subtle basslines beneath.

The accompanying app gives you an equaliser and the ability to pair your Minirig with another speaker to create a mega sound system.

Marshall Middleton

Marshallheadphones.com, £269.99

The Marshall Middleton has a lot going for it. It's sleek and stylish, built in a robust casing, and pumps out a rich sound in all directions. And thanks to its IP rating and strong frame, it can also take some falls, bumps and spills.

However, there are two crucial factors that hold this speaker back from being the perfect portable device. Firstly, it's pricey. At a penny shy of £270, it costs more than most of its equivalent competitors.

Secondly, for its size, the Middleton weighs far more than it realistically should. It's going to weigh down any bag you intend to carry it around in, and with its bulky size, isn't exactly the most portable speaker out there.

If you're happy to deal with these two factors, then the Middleton is a fantastic purchase, thanks to its combination of style and high-performance sound.

OB-4

teenage.engineering, £485

Gadgets need a little magic. That seems to be the philosophy behind Teenage Engineering's playful take on the portable Bluetooth speaker and radio.

On sound alone, the OB-4 stands out; it's warm, rich, detailed and easily among the best we've heard at this price. It's loud too, claiming to be able to reach 100 decibels, which we didn't dare go near. Plus, the battery will last 72 hours at 'normal' volume.

The design is second to none: a nod to old-school hi-fi while still looking modern and clean. Beneath the unfussy exterior, the speaker is packed with quirks designed to make you fall in love. Take, for example, the 'tape' wheel that lets you adjust the play speed, rewind and even cut loops of music. It's just a shame there's no line out and no DAB, but who said love requires perfection?

Ideas we like...

Our pick of the month's smartest tech

→

...A jacket that opens itself

There are not enough opportunities in life to really feel like Batman. Nike's new Aerogami jacket gives you one. Sure, it's not bulletproof, and it doesn't conceal a pair of wings, but the Aerogami gets you close to that feeling of badass preparedness with its unique design (plus, it comes in black). Through the use of a moisture-reactive material, the jacket reacts to your sweat. Get a good workout going and vents on the front and back of the Aerogami open to cool you down. Once you're cool and dry again, the vents close back up. Nike isn't the first to do this, but it's the first to do it without having a battery and wires running through the garment.

Nike Aerogami jacket
Nike.com, £TBC

...Finally, a Google tablet

Technically, Google has been making tablets since 2012, and even tried to make an iPad killer in 2018. But for Google's sake, it's best to pretend none of that ever happened. Instead, we can act like this is Google's first attempt at making a tablet. Like its competitors from Samsung and Apple, the Google tablet is powerful, has a high-quality display and is stylishly designed. It stands out by coming with a magnetic charging dock that allows the tablet to double up as an alarm clock, smart home controller, recipe book and everything in-between.

Google Pixel Tablet
Store.google.com, £599

...Speakers for all-weathers

In its latest round of focus groups and customer research, Skullcandy must have fixated on one word: 'clumsy'. Its new range of Terrain speakers are built to be dropped, drowned and, by the looks of things, treated pretty terribly. The Terrain can be submerged for 30 minutes, offers 14 hours of battery life and is built with an impact-resistant construction. Three sizes of speaker are available with the durable Terrain exterior (there are Mini and XL models too) and you can even pair a few together for a surround sound effect.

Terrain speaker
Skullcandy.co.uk, £49.99

....LEGO for the biggest space fans

In a world of VR, metaverses and an ever-growing dictionary of techno jargon, it'll come as no surprise that LEGO has embraced apps and augmented reality. Its new Mars Rover Perseverance set is a replica of the famous robotic Red Planet explorer made up of 1,132 pieces. And through the accompanying app, you can use it to virtually explore Mars, picking up samples and roaming 'real' Martian locations (albeit ones overlaid on your living room floor).

LEGO NASA Mars Rover Perseverance
Lego.com, £84.99

...The robot revolution begins here

If dog training hasn't been going too well and it's left you desiring a more obedient pet, why not try a robot? The XGO Mini2 Robot Dog is intended for anyone who is more fascinated than terrified by the videos of Boston Dynamics' Spot robot and wants a fun (expensive) version of their own. An associated app gives you complete control over the dog and for the more technologically advanced, it can be hacked through its Raspberry Pi chip.

XGO Mini2 Robot Dog
UK.robotshop.com, £999

IDEAS WE DON'T LIKE...

....SUNGLASSES FOR READING BOOKS

Reading is relaxing, right? What about if you held the book just a few centimetres from your face? In fact, what if the book was two tiny screens integrated into a pair of glasses? While it sounds like the concept for a James Bond gadget Q was happy to leave on the drawing board, this is actually the company SOL's attempt at revolutionising the reading market. The "wearable e-reader" is controlled by an app and a small remote that you use to turn pages. It has the added benefit of making you look extra anti-social as you wear fully blacked-out glasses indoors, as you read your latest spy thriller.

SOL Reader
Solreader.com, $350

...A VIRTUAL MULTI-MONITOR SET-UP

The tech companies of the world are betting big on virtual offices in the metaverse. Few others seem convinced, but it isn't stopping wannabe tech titans from developing virtual office equipment. One such concept is Sightful's Spacetop, "the world's first augmented-reality laptop". By combining VR glasses with a keyboard and trackpad, the Spacetop provides you with an array of virtual monitors. It's clever, but if VR has shown us anything, it's that this is a recipe for motion sickness, technical issues and a raging headache... oh, and an empty bank account (early access costs $2,000).

Spacetop
Sightful.com, £TBC

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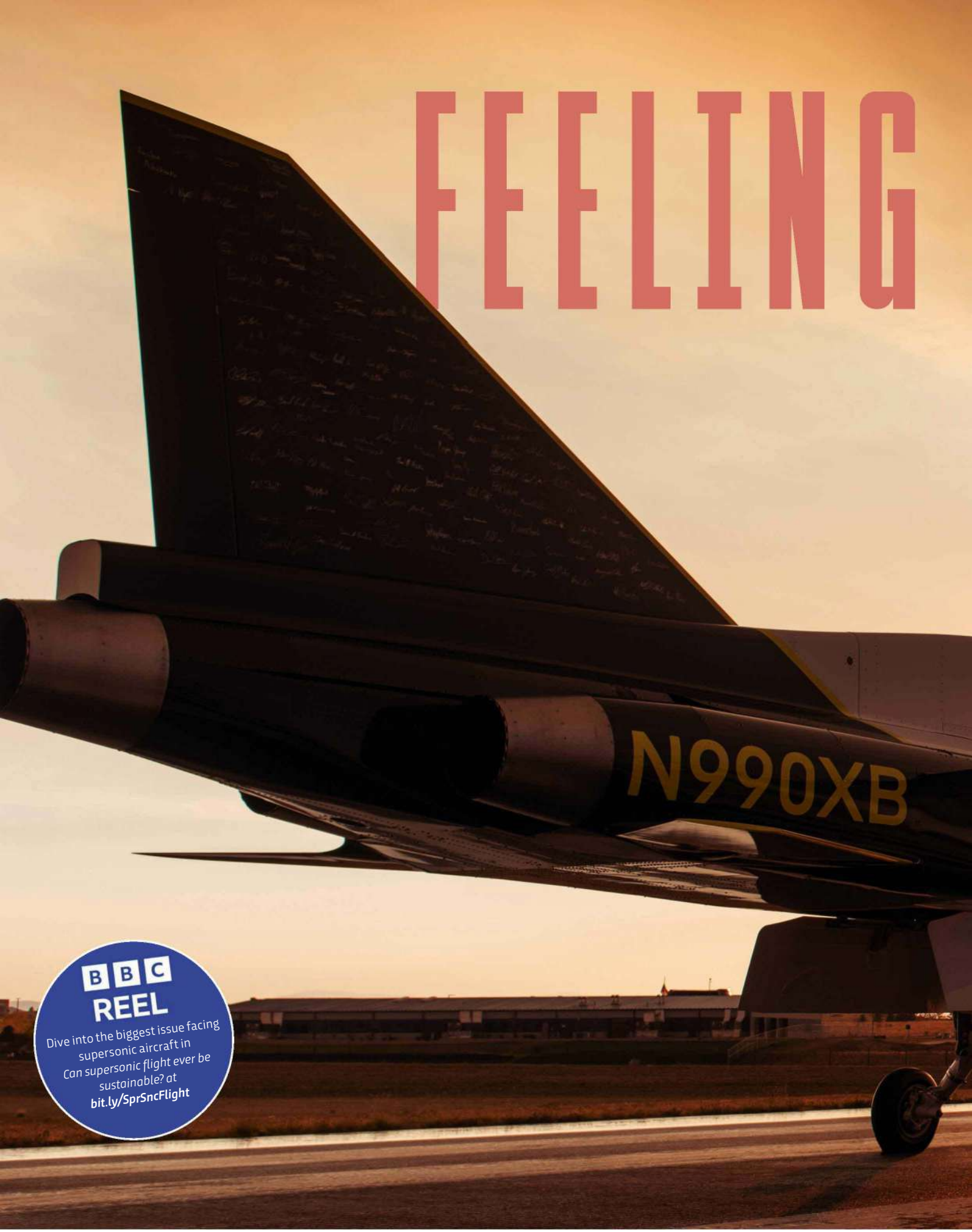


BBC REEL

Dive into the biggest issue facing supersonic aircraft in *Can supersonic flight ever be sustainable?* at **bit.ly/SprSncFlight**

SUPERSONIC

IT'S 20 YEARS SINCE THE PUBLIC COULD BUY A TICKET TO FLY ON A PLANE CAPABLE OF BREAKING THE SOUND BARRIER. BUT THERE'S A BAND OF ENGINEERS AND PILOTS WHO THINK COMMERCIAL AIRLINE PASSENGERS ARE ONCE AGAIN FEELING THE NEED... THE NEED FOR SUPERSONIC SPEED

by STEPHEN DOBIE

BOOM SUPERSONIC

The XB-1, due for its first test flight later this year, is blazing a trail for the next-generation of supersonic passenger aircraft

November will mark the 20th anniversary of Concorde's retirement. And with it, a lengthy pause on regular, paying airline passengers (albeit those with healthy bank accounts) travelling faster than the speed of sound – 343 metres per second, or 761mph (1,224km/h).

Many still mourn the distinctive, dart-shaped aircraft's loss, deeming its costly tickets, urgent fuel use and thunderous sonic booms when it breached the sound barrier as acceptable prices to pay for being propelled across the Atlantic at Mach 2 (over 1,500mph or 2,400km/h).

Supersonic travel looks to be on its way back, though, and in a cheaper, cleaner and quieter form. "Concorde was a technical marvel and well ahead of its time," says Ben Murphy, vice president of Sustainability at Boom. "But it was a nationalistic project that hadn't been built around a viable economical model."

Boom is an American company aiming to fly passengers supersonically by the end of the decade on its new Overture aircraft.

"We can build on Concorde's legacy with nearly 60 years of advancement in aerodynamics, materials and propulsion systems," Murphy says, "with the use of sustainable aviation fuel (SAF) enabling the return of supersonic travel in an economical and environmentally sustainable manner."

SAF is seen as the most viable route to reduce the carbon footprint of aviation and can cut a plane's lifetime carbon dioxide emissions by 80 per cent. It can be made by recycling waste materials from landfill and food production, or produced synthetically by carbon capture from the air. SAF can also be mixed in a 50/50 ratio with regular aviation fuel to partially decarbonise the airline fleets operating right now.

THE VIABILITY OF SUPERSONIC TRAVEL

Overture's propulsion is based entirely around SAF, with Murphy and his team all too aware that the aircraft's green credentials are vital to the project winning favour.

"Concorde was famously loud and dirty, [powered by] afterburning military-derived engines that produced a lot of particulate matter. That's the image people have in their mind," says Murphy. "We'll travel twice as fast as a regular subsonic passenger plane over water [around 1,300mph or 2,090km/h] and 20 per cent faster over land [just shy of 700mph or 1,100km/h], meaning we'll burn up to 2.5 times as much fuel per flight, but with SAF giving us a net zero carbon footprint."

In the early stages of the project the team at Boom purchased old Concorde seats – "they're basically an economy-class seat today" – to work out how to arrange the 64-80 business-class seats that'll sit in each Overture. The thinking behind the smaller seats is that the faster journey times Overture will offer, makes the luxury of bigger, fully reclining, 'lie-flat' seats, as found in the more premium classes of today's long-haul flights, unnecessary.

Overture's longer range – 4,250 nautical miles [approx 6,850km] versus Concorde's 3,900 [6,270km] – opens up more than 600 economically viable routes and much greater variety than its forebear, with LA to Sydney possible with a fuel stop. Its top speed of Mach 1.7 (1,304mph or 2,098km/h) lags a little behind →

ABOVE Measuring almost 20m (65ft) long, with a 5m (17ft) wingspan, the XB-1 is powered by three jet engines and has a carefully shaped nose designed to ensure stability over a wide range of airspeeds

BOOM SUPERSONIC

"WE'LL TRAVEL TWICE AS FAST AS A REGULAR SUBSONIC PASSENGER PLANE OVER WATER AND 20 PER CENT FASTER OVER LAND"

BOOM

"OVERTURE'S DEBUT FLIGHT IS SCHEDULED FOR 2027, WITH PASSENGERS DUE TO TRAVEL BY THE END OF THE DECADE"

→ Concorde's Mach 2, but also negates the need for noisy afterburners, a fuel-guzzling solution usually found on military jets to increase the thrust of an engine.

London to New York in around four hours (versus Concorde's three hours and 20 minutes) is still significantly quicker than a business-class flight at subsonic speeds.

Overture's expected routes will largely be over water, with supersonic travel currently prohibited over land to save those of us on the ground from the disruption of sonic booms. "We've made a software set that predicts where the sonic booms will propagate to find the fastest route," says Murphy.

BENCHMARK FLIGHTS

Overture won't be the first Boom aircraft to fly, however. The company's XB-1 experimental craft is set to make its first test flight in Mojave's supersonic corridor, in California, later this year.

Overture's debut flight is scheduled for 2027, with passengers due to travel by the end of the decade (with tickets expected to cost a little more than those of business-class prices). By the early 2030s, Boom hopes to be making 66 Overtures a year at its North Carolina plant.

Given those ambitions, what does Murphy have to say to anyone scaling back their air miles in pursuit of a greener planet? "Sometimes it gets lost that travel brings a lot of benefits," he says. "A more connected world has brought huge economic growth and cultural exchanges lead to a more peaceful planet. We want to make people feel good about travelling. You can both travel *and* protect the planet. It's not an 'either/or' situation with the technology we're working on today."

It's a view echoed by Mike Bannister, British Airways' chief Concorde pilot from 1995 until the aircraft's retirement in 2003 and an occasional →

ABOVE Production of the Overture, illustrated here, is due to start in 2025, ahead of its maiden flight, expected in 2027

LEFT The Overture aircraft will use four Symphony jet engines, which are currently being developed to produce 35,000lb of thrust and run on sustainable aviation fuel

BOOM SUPERSONIC X2

"THE ISSUES OF AIRCRAFT HEATING EXPAND EXPONENTIALLY AS YOU TRAVEL FASTER"

TOP LEFT The shockwaves produced as an aircraft passes through the air at supersonic speeds are what cause the loud booms heard by people on the ground

LEFT NASA is working on the design of its X-59 aircraft, which it hopes will reduce the loud booms produced when breaking the sound barrier to a level that will enable the ban on supersonic flight over land to be lifted

NASA X2

→ advisor on the Overture project. He clocked 9,000 flight hours on the legendary passenger jet before its final flight, with 7,000 of them above the sound barrier, likely making him the most frequently supersonic human who isn't an astronaut.

"I'm an optimist – I think humans never take a backward step for too long," says Bannister. "My daughter is a commercial pilot on a 737. She was 10 when Concorde retired and she said, 'But dad, I really wanted to fly supersonically'. I think she now has a chance."

Bannister's career high came as he flew in formation with the Red Arrows for Queen Elizabeth II's golden jubilee in 2002 (Her Majesty and two million spectators waving up at the cockpit as he buzzed the capital at 1,000ft/300m) little over a year before he landed Concorde for the final time. "We didn't know at that point," he admits.

The reasons for the aircraft's retirement were numerous, but ultimately financial. "In the 1990s we looked at modernising the controls," Bannister says. "By this point, Concorde was making £1m profit per round trip per day, so the cost of grounding one [of British Airways' fleet of seven] for a year of recertification was too high."

He estimates the plane could have soldiered on to 2015 with enough money behind it.

"The seats might have been small, but they were built to 1960s standards," says Bannister. "And the short time you spent on board, actually sitting in them, more than compensated.

"Even though you flew at 60,000ft [approx 18,000m – 20,000ft/6,000m higher than a subsonic plane] its cabin was pressurised for a lower effective altitude than regular flight. Crossing the Atlantic, you'd basically spend three hours and 20 minutes up a 5,000ft hill [in terms of cabin pressure] rather than eight hours up an 8,500ft mountain."

The draws of travelling aboard Concorde didn't end there, though. "At supersonic speed, you travel so quickly you go faster than Earth rotates," explains Bannister. "So the Sun appears to go backwards, which scientists tell us resets the body clock. To all intents and purposes, it eliminated jet lag."

A SMALLER BANG

"Overture looks a lot like Concorde, but that's understandable," says Bannister. "The issues of aircraft heating expand exponentially as you travel faster and there's probably only one optimal solution. I flew the first generation of supersonic travel and Boom is launching the second. But the third is when we can reduce the impact of the sonic boom to allow supersonic travel over land. That's the Holy Grail."

And it's a target firmly in the sights of the engineers behind X-59 QueSST, a Mach 1.4 experimental aircraft produced by Lockheed Martin as part of NASA's pursuit to suppress the aural impact of the sonic boom.

X-59 QueSST's first flight is due by the end of 2023, two years later than initially planned. It'll conduct what are dubbed 'community flight tests', amassing US residents' views on its suppressed 'sonic thump', which aims to reduce Concorde's 110-decibel sonic boom (about the same perceived loudness as thunder), to around 75 decibels (equivalent to a car door being shut).

The trick is to separate the shockwaves caused by the plane pummelling the air beyond the sound barrier. It's thought you can do that by refining the shapes and inlets of an aircraft's nose, wings and tail so that those waves don't coalesce before they reach the ground.

Adjustable bodywork could allow pilots – or, indeed, algorithms – to react to flight data to ensure a supersonic plane's acoustic signatures remain quiet during a journey. Planes flying faster than the speed of sound currently drop sonic booms to the ground the entire time they're supersonic.

"The X-59 is just one critical step in the process of making supersonic travel commercially viable," says its programme director David Richardson. "It proves to the general public and to regulators that quiet supersonic flight is achievable, thereby making supersonic commercial flights practical if they can now go over land."

He sees 2037/2038 as a target for a passenger jet being both technologically and legally capable of doing so. "We're very excited about the potential change this could have for everyone, including me and you. It'll likely always be more expensive than an economy ticket on a large subsonic airliner – but remember, you'll get there twice as fast."

Keeping things below Mach 1.8 (and so foregoing afterburners) reduces fuel costs and simplifies servicing, a cost saving that ought to make its way to the passengers buying and sitting in the seats. All told, the new supersonic era looks a lot more democratic than the old one. The fate of whether it's truly cleaner and quieter now lies in some very enthusiastic hands. **SF**

—

by **STEPHEN DOBIE**

Stephen is a freelance journalist formerly of BBC Top Gear magazine. *He has a passion for most things with an engine.*

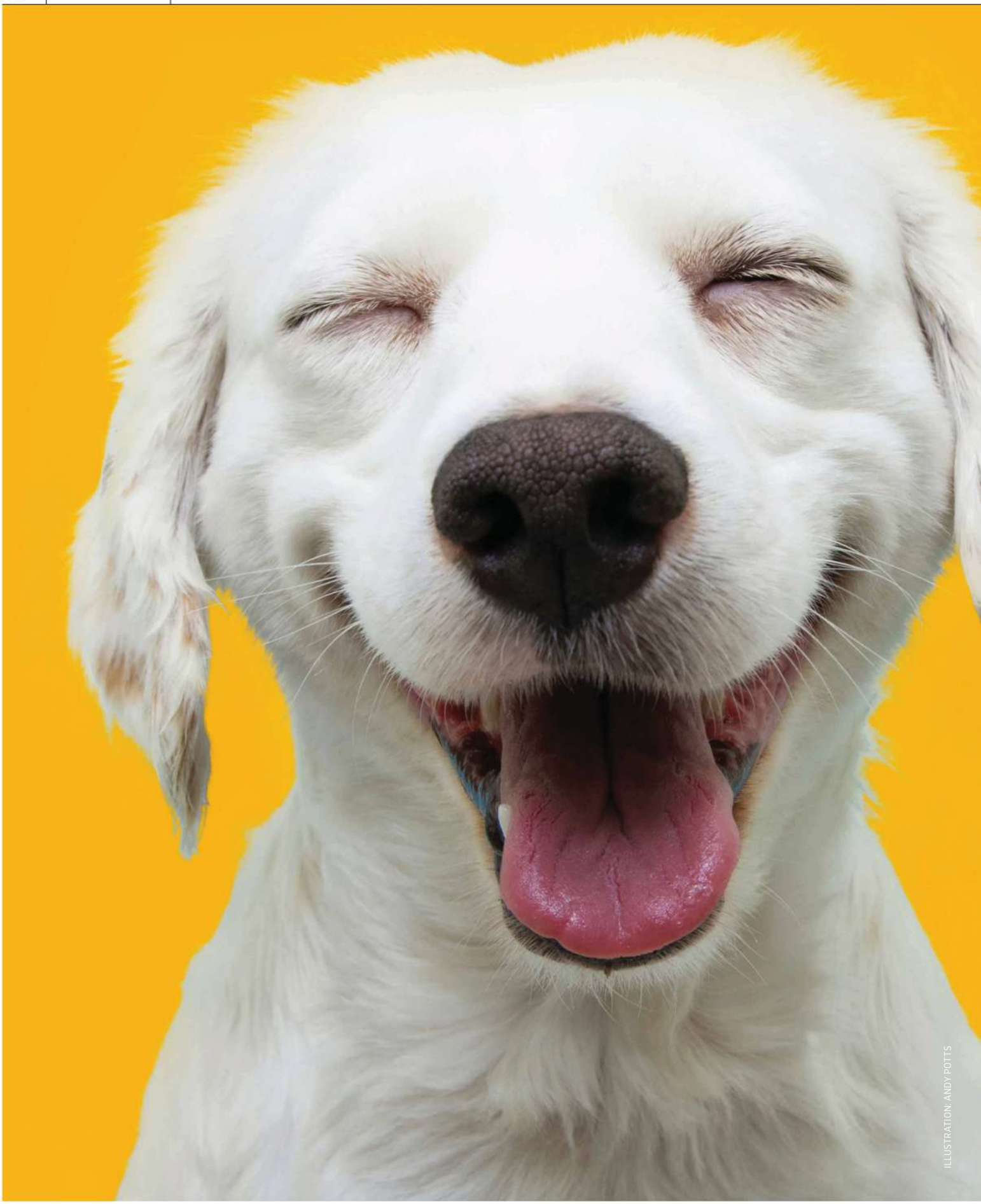


ILLUSTRATION: ANDY POTTS

OUR BEST FRIENDS

Many of us share our homes and lives with a canine companion. But how much do we really know about what's going on inside their heads? Cognitive scientists Dr Zazie Todd and Prof Alexandra Horowitz explain what we're learning about how our four-legged friends think, and share a few tips on how you can make their lives better...

GETTY IMAGES

DOES YOUR DOG REALLY LOVE YOU OR DO THEY JUST LOVE BEING FED BY YOU?

Your dog is so pleased to see you when you get home. Then again, that's also when you feed them. So does your dog see you as their best friend or merely a food delivery system?

You won't find the word 'love' in the published papers of scientists who research non-human animals. Ironically, though, most animal behaviour scientists were drawn to the subject because of their deep and abiding interest in them.

And yet, generations of researchers have been trained not to use anthropomorphic words like 'love' to describe something a non-human animal might be feeling.

Indeed, the use of anthropomorphisms (descriptions of non-human behaviour or characteristics with terminology used to describe humans) has long been condemned in the field of animal behaviour. Hence, researchers talk of 'temperament' instead of 'personality' and 'positive cognitive bias' instead of 'optimism'.

This hard-line stance against the applicability of human terms to non-humans is loosening, however. Partly for the usefulness of some of the terms for describing animal behaviour, but also for the strong evolutionary reasons to believe that non-human animals are not entirely dissimilar to humans.

What is clear to anyone who observes dogs' behaviour, is that dogs are hopelessly fond of us. We could call it 'hypersociable' or 'socially preoccupied'; we could call it 'excessively affectionate'. Or we could call it loving. Even so, another puzzle has arisen: how does one recognise an anthropomorphic concept like 'love'? In other words, what are the defining behaviours or neurological features of love that one might look for in a species without the verbal capacity to say, "Yes, I feel love."

So far, the answers have come in terms of behavioural measures (what dogs do that looks like love) and physiological measures (how their bodies change in ways similar to our bodily changes when we're besotted).

If you live with dogs, you may have heard of – or are experiencing – separation anxiety: distressed, anxious and sometimes destructive behaviour a dog performs in your absence. This disorder is really an exaggerated form of attachment, a word first used to describe the relationship between mother and child.

Tests for attachment involve monitoring a child (or dog's) behaviour when separated from the mother: distress at separation and calming at reunion indicates attachment. This bonding is part of the process of developing a loving relationship: that such occurs in dog-human relationships (even in a disorderly way) looks like the same thing.

One strain of research looks at dogs' sensitivity to our emotional states, such as coming close when we're crying or upset. This behaviour looks like an expression of love, too, although it remains uncertain whether they're trying to console us or just worried about the unusual hormones and sounds we're making.

On the other hand, some behaviours that look loving, such as a greeting 'kiss', are just as likely to be a vestigial behaviour as an expression of

"JUST BEING WITH THEIR PERSON CAN CAUSE A DOG'S OXYTOCIN LEVEL TO RISE"

affection. Dogs' closest ancestors, wolves, greet packmates returning from a hunt with such 'kisses': a greeting, yes, but also a request for the hunter to regurgitate some of the bison they just consumed.

Physiologically, research that might speak to whether dogs love us comes from looking at their heart rates, hormones and brains. In one small study involving dog-human pairs who were especially bonded, researchers gave both dog and person heart rate monitors, separated them briefly, and then reunited the pairs. On reunion, the heart rate of both dog and person dropped, and the drops even appeared to be aligned – two hearts beating as one.

Similarly, you may have heard of a hormone called oxytocin. Oxytocin is a neuropeptide: a kind of compound that acts on the brain. And it's one with a special role for humans: it's held to be the neurological reason parents' bond with their infants. Dog researchers have found that oxytocin plays a role in the dog-person bond, too. Just by gazing at each other, rates of oxytocin rise in dogs and in their person. The stronger the bond you have, the more of an effect we find. In fact, just being with their person can cause a dog's oxytocin level to rise.

There's no specific section of the brain that is singularly active when looking at, or thinking about, someone we love, but fMRI imaging of some dogs' brains shows activity in a reward centre – the ventral caudate – both when looking at something they loved (hot dogs) and when hearing the praising voice of their person. It's not a home run, but, at a minimum, it shows they view us as at least as desirable as processed meats.

That said, they're no dummies. In a typical dog-human relationship, as we've defined it, the human is the one in charge of the food and the dog must wait, patiently or not, for us to dole it out. Dogs are very good at making associations, so it doesn't take them long to associate you with the food you deliver. Far from being manipulative, the dog who does your bidding for a treat is just being savvy.

DO DOGS HAVE TO HAVE THE LAST WORD?

It's not so much that dogs like to have the last word, more that barking can be a group activity that they all want to join in on. Dogs use barks in several different ways: they can be a greeting to say hello, a warning (for example, that a stranger is approaching), a request for attention when left alone or wanting something, and part of play. Barking is what's known as an allelomimetic behaviour. In other words, a behaviour that other dogs are likely to copy. So when one dog barks, other dogs are likely to start barking too.

GETTY IMAGES X3

WHY DO PUPPY-DOG EYES WORK?

You've said no to more treats or stopped your dog from climbing up on the sofa. Then they hit you with those eyes...

Since dogs began diverging from wolves tens of thousands of years ago, they've been changed for us, and by us, to suit us. This makes sense: natural selection describes how animals who have traits well suited to their environments are more likely to survive and bear young themselves. Artificial selection, the process of domestication, by which humans have taken over the role of nature in determining who survives and can breed, is quite similar. Those animals who have traits well matched to us are more likely to be kept by us, and survive.

Thus, animals who we like – who we find useful, or cute, or cute and useful – will be successful. Another way of looking at this, though, is that those animals who have traits we like are good at using us to succeed.

The dog is a case in point. Initially, there was almost certainly no intentional breeding by humans; rather, those proto-dogs or wolves who were the least fearful of us were most likely to be allowed near our homes and communities. Over time, we began keeping dogs for functions they served: as guards or as hunting companions, for instance. Those who were kept were more likely to mate – or be mated – with other dogs serving that role. The rise of purebreeding, breeding for looks more than for function, only arose over the last 200 years. But all along, we likely selected inadvertently for dogs who looked the way we liked and acted the way we liked.

This is where the 'puppy-dog eyes' come in. First, as a result of domestication, dogs typically have a neotenised, or juvenile, appearance. They even behave in some ways more like young animals, playing together into adulthood (something much more rare among wild animals). Even when grown up, they retain a kind of infantile appearance. Human babies have extra giant heads (relative to the typical adult head), big cheeks, chubby limbs and big saucer-like eyes. It's thought that this prompts a human response to care for these helpless young humans. It turns out, in implicit preference tasks, humans prefer the look of dogs with large, baby-like eyes too.

But dogs do something special with those large eyes, something unlike what their nearest ancestors, wolves, do: they gaze at us and look into our faces. We humans look at each other's faces in communication and empathy – and so do dogs. For wolves, by contrast, most eye contact is a threat. (Don't try to share a loving gaze with a wolf if you come across one.)

So dogs are already looking at our eyes, and we at theirs, and this enables the feeling of mutual understanding. But on top of that, researchers in Germany found that, unlike wolves, dogs have a special muscle, known as the *levator anguli oculi medialis*, or LAOM, muscle above their eyes. It allows them to raise their inner eyebrow in a beguiling way that reads as an appeal or as sadness.

Humans make this eyebrow movement, too and we're deeply attuned to it – perhaps even primed to respond to it. And it turns out that dogs living in a shelter who use their LAOM muscle when a person wanders by, are more likely to be adopted than the dogs that don't. A second eye muscle, the *retractor anguli oculi lateralis* (RAOL) muscle, pulls the outside corner of the eye back, enabling them to nearly smile with their eyes. The combination certainly prompts a nurturing response from us.

Are these large, human-gazing, eyebrow-raising puppy eyes just 'manipulating' us, as is sometimes said? Well, insofar as humans have almost certainly artificially selected dogs who have these familiar and beguiling expressions, it's we who are the manipulators. Of domestic dogs' physical features and of ourselves.

The *levator anguli oculi medialis* muscle above dogs' eyes lets them raise their inner eyebrows

"DOGS DO SOMETHING SPECIAL WITH THOSE LARGE EYES – THEY GAZE UP AT US"

GETTY IMAGES, ALAMY

HOW WELL DO DOGS UNDERSTAND US?

Ever get the feeling your dog knows what you're thinking? It might be because they're picking up on cues you didn't realise you were transmitting

Clearly, dogs are quite good at understanding us. But how far does this go and how are they able to understand our emotions – what cues are they reading?

A dog who has lived among people is a much better reader of us than we are of them (or, one might suggest, of ourselves). In a way, dogs are anthropologists: they spend a lot of time observing us and thus learn associations between behaviours we might not know about ourselves.

In the home, you might see this in their learning to predict the difference between you getting up to take them out and getting up to go to the fridge. From studies with owned dogs, we also know that they can read stress and even detect fear, and they can identify the presence of diseases that we don't know we have. Part of their skill is due to their acute sense of smell, but, despite not being bipedal and having no hands, dogs know about our bodies.

When interpreting others' feelings, we tend to focus on peoples' heads (and on dogs' heads, too). They read our faces, as well. Several studies into how dogs perceive human emotional expressions found that they're good at distinguishing happy human faces from faces with blank expressions and happy faces from angry ones, and can even match a photo of a happy or angry face with a vocalisation in the same emotional tone.

They can use a person's facial expression when opening a box (a look of delight or disgust) to choose if they want to approach that box themselves. And they can identify these expressions even when presented with a photo of only the top half of the face (so even if that face is hidden by a COVID mask).

They know our voices (they can match a stranger's voice to their gender, and recognise their person's voice) and they know our smells (they recognise their own person's odour on a t-shirt and distinguish it from a stranger's odour). Recently, researchers have confirmed the claim that dogs recognise fear: they're able to discriminate t-shirts containing the odour of someone who was afraid (watching a scary movie) from those from someone watching something more benign. They can also certainly see our fear, and stress, in our changed body language. One study even found a correlation between the testosterone level of a person (depending on whether their sports team won or lost) and the dog's cortisol, or stress, level.

Through studying thousands of hours of human behaviour from their side of the living room, dogs come to know our minds. For instance, one study found that dogs know when we're doing something intentionally (such as putting something desirable out of their reach) or unintentionally (such as accidentally dropping something desirable out of their reach) and will behave differently when the action is unfriendly or just clumsy. Several studies have confirmed they know that if we're not in the room with them – or just turned away – they can get away with eating something they've been forbidden from eating. But they also recognise when our noses are glued to a book or our eyes are glued to a computer as indications that they can also get away with eating it, sooner than if our eyes are on them. More broadly, they think about knowledge states: dogs distinguish people who are knowledgeable and ignorant about the source of hidden food, recognising that if someone wasn't in the room when it was hidden, their gestures about where to find it are not worth following.

"RECENTLY RESEARCHERS HAVE CONFIRMED THE CLAIM THAT DOGS RECOGNISE FEAR"

Finally, and most impressively, they can smell our illness. From the very first reports of pet dogs who identified melanomas on their people (annoyingly biting and scratching at parts of the owners' bodies), several teams of researchers have been at work training dogs who can, now, identify various cancers by smell, alert a diabetic when their blood sugar rises precipitously, and even smell COVID.

GETTY IMAGES, ALAMY

WHAT DO DOGS SMELL WHEN THEY SNIFF EACH OTHER... OR THE PAVEMENT, OR A TREE TRUNK?

Dogs will happily put their noses in some unpleasant places. So what are they expecting to find out from them?

Every meeting of dogs usually starts with an introduction that involves a good butt sniff. What data are they gathering with this form of greeting? Indeed, when they leave their scent on something and smell scents left by other dogs, what information are they getting?

Big-brained we humans might be, but we're little-nosed. We're visual creatures, interpreting the world first through sight; dogs are olfactory creatures, seeing that same world as a smell landscape. The difference highlights how hard it can be for us to imagine that dogs are sniffing anything at all on the pavement when we see 'nothing there', or how baffled we are when they go to sniff another dog's rump for the seventh time.

To begin to understand it, look at where your gaze lingers when you meet another person: do you look once and then quickly look away, never to let your gaze alight on them again? When you visit a museum, do you stand in front of a painting for a mere moment before turning away, or do you sometimes linger for minutes or hours, examining the image from different directions, at different distances, even exclaiming with pleasure or wonder?

As we see the world, so dogs smell it. They have hundreds of millions more olfactory receptors in their noses than we do, each of which grabs odorant molecules out of the air and converts that smell into neural signals to the brain. Their noses are long warming and humidifying chambers lined with special tissue that allows them to deconstruct multifaceted smells, even before they reach the receptors. Dogs can sniff up to seven times a second, and have a brilliant way of exhaling: out the side slits of their nostrils, so their exhale does not interfere with their steady inhale of the smelly vista in front of them.

Simply put, the anatomy and physiology of dog sniffing should begin to allow us to see how they're operating on a different olfactory level than we are. When dogs sniff each other, they're finding out about each other. (And by the way, males tend to approach an unknown dog's rump first, while females most often aim for the head first.) Their vision is perfectly good (they're nearsighted, have two-colour vision and especially keen night vision), but it's in our signature smells that reveal who we are to an olfactory animal. Everyone has a smell and, at minimum, our chemical exudation includes information about our sex, our health and what we've recently eaten. It has information about our stress levels and our emotions; for female dogs, it has information about their estrous cycle. In essence, it has information about who we are. That's what a dog is sniffing out in another dog – and when they're greeting you (you may have noticed that they love to stick their snouts in some of our smelliest areas first: our mouths and our groins).

Some ask why, if the dog's sense of smell is so keen, don't they stand at a polite distance and sniff surreptitiously at each other. It makes more sense to wonder why we humans find it off-putting to smell each other, when most mammals are happy to get close for a sniff. The closer you get, the more information you can perceive: the brush strokes of the scene, not just the overall colour or form.

Since nearly everything has a smell, and as most animals (including the human animal) slough off skin and fur as we move, the ground holds a tale of our passing, for any animal willing to sniff closely. Indeed, research has shown that tracking dogs can determine which way a person has fled by sniffing just five footprints, as they're able to distinguish the amount of odorant left behind in the first (older) and fifth (newer) print. In this way, dogs can smell the passage of time: older scents are on the ground and more degraded; newer scents are brighter and, maybe, still in the air. Not just a tracking dog but also your dog can detect, on leaving your flat, if someone has recently passed by, from sniffing the air. But they can also smell them in odour fallen on the ground, or, if the passerby is a dog, in the urine they've usefully left on a tree trunk.

DOGS: A USER'S GUIDE

Learn more about what your dog is doing or trying to tell you with its expressions, actions and noises…

SMELL

Dogs can recognise other people and dogs by their smells. Dogs can recognise the smell of their own urine.

Male and female dogs scent mark with urine. Sometimes they scratch the ground at the same time.

When meeting another dog, dogs typically try to smell the side of the head and neck, or the rear end of the other dog – often while moving their own rear end away, as if to prevent it being sniffed.

The olfactory epithelium in a dog's nose is up to 150cm² compared to just 5cm² in humans.

Some of the things dogs have been trained to sniff out include: *C. difficile*; illicit drugs; wildlife scat (for example, grizzly bears); missing people; dead bodies; a drop in their guardian's blood sugar; and invasive species, such as zebra mussels.

fMRI scans have shown that the reward centre of dogs' brains (the caudate) lights up when they smell their guardian.

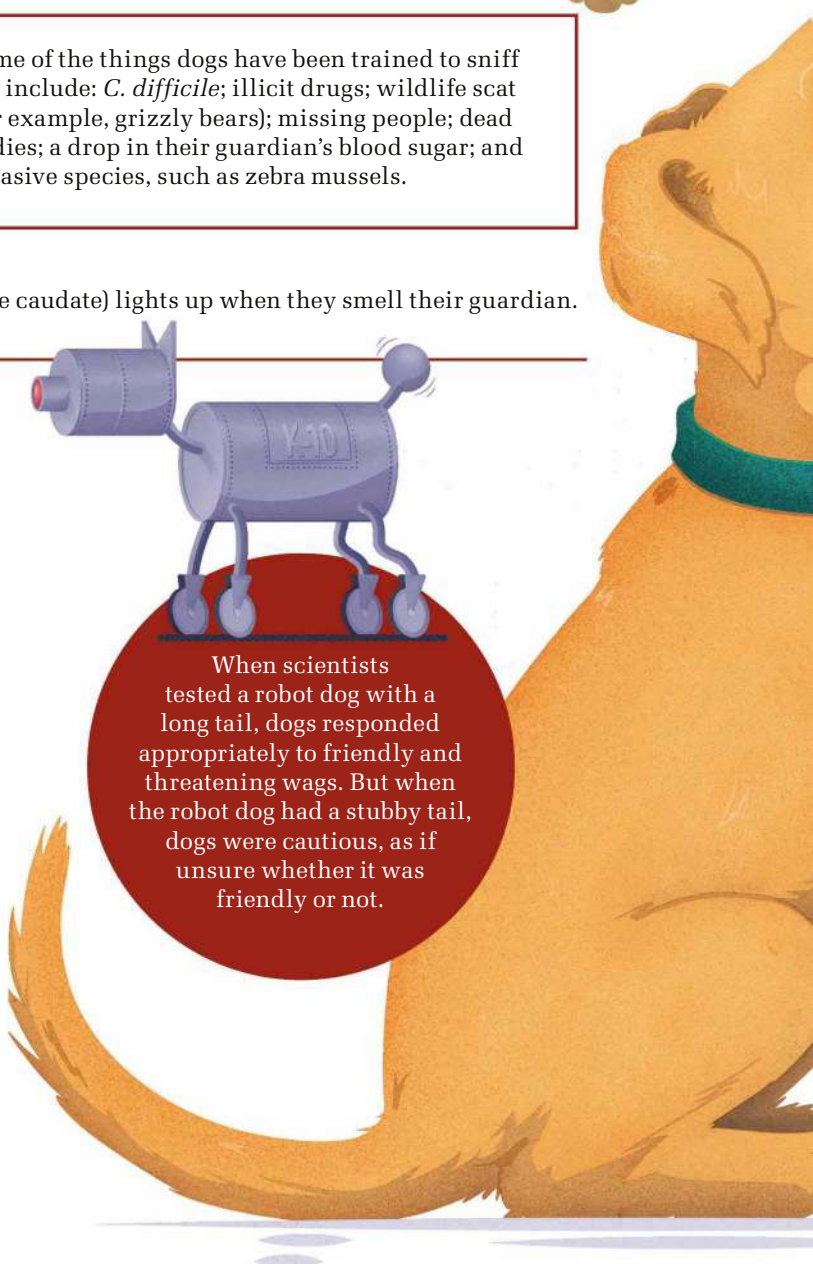
TAIL

A loose, wide tail wag is friendly and happy.

An erect tail with a short, stiff wag is a warning.

The tail wags more to the right when dogs see something positive (believed to involve the left hemisphere of the brain in processing) and more to the left when seeing something negative (thought to involve the right hemisphere).

When scientists tested a robot dog with a long tail, dogs responded appropriately to friendly and threatening wags. But when the robot dog had a stubby tail, dogs were cautious, as if unsure whether it was friendly or not.



BARKS AND GROWLS

Dogs and people can tell the difference between an ‘alone bark’ (high-pitched) and a ‘stranger bark’ (lower frequency, longer).

The barks people find most annoying are high-pitched with low tonality.

Growls are low frequency and signal that the dog is uncomfortable.

But dogs also growl in play. This type of growl has a higher frequency and is shorter.

ILLUSTRATION: DANIEL BRIGHT

EARS

Ears forward is a sign of interest.

Ears back or flattened is a sign the dog is fearful, perhaps threatening.

‘Aeroplane’ ears (out to the side) are thought to mean the dog is unsure.

Variations in the ear shapes of different breeds can make it harder to interpret the dog’s emotional state.

DOGS THROUGH THE AGES

25,000 – 40,000 years ago Dogs are domesticated from the ancestors of modern wolves.

5,000 – 10,000 years ago Dogs are already specialised, with hunting dogs (similar to modern-day salukis), mastiffs, terriers, pack dogs and lap dogs.

420 – 1066 CE Early mediaeval dogs are bigger than Roman dogs at 60cm (23in) tall, but also less varied. Most dogs have a role: guarding, herding, hunting, fighting or sitting on laps.

476 CE to approx. 1450 Mediaeval hounds are specialised: wolfhounds, deerhounds, foxhounds, etc. (not necessarily related to modern dogs).

Mid-16th to mid-19th century The turnspit dog is used in kitchens to run in a wheel and turn a spit to roast meat. The invention of the mechanical roasting jack eventually leads to the end of this breed.

1800s Free-roaming dogs are an issue in London and other cities, blamed for noise, defecation, biting and madness.

1859 to 1861 The first dog shows to judge dogs on looks are held, alongside agricultural shows, in Newcastle, Birmingham and Leeds.

1860 The Temporary Home for Lost and Starving Dogs is opened, ultimately becoming Battersea Dogs’ Home.

1864 The Bulldog Club is the first national club to be formed for a specific breed of dog. About a decade later, it’s joined by the Mastiff Club, the Bedlington Terrier Club and the Dandie Dinmont Club.

1865 The first-ever conformation standard for a breed, the pointer, is published. This was the start of the modern pedigree dog.

1873 The Kennel Club is founded in London, the first such organisation in the world.

1891 The first Crufts dog show takes place at the Royal Agricultural Hall, Islington, London.

1925 Sled dogs, including Balto, delivers life-saving serum from Anchorage, Alaska, to Nome, amid a diphtheria epidemic.

1989 The creation of the labradoodle kicks off the trend for designer dogs.

1991 The Dangerous Dogs Act bans four breeds of dog in the UK.

2014 The RSPCA publishes its report, ‘Breed-Specific Legislation: A Dog’s Dinner’, arguing for an end to breed-specific legislation.

2017 Analysis of genetic data allows scientists to publish a cladogram (essentially a genetic map) that shows relationships between domestic dog breeds. Among the findings, the pug seems to have contributed to many other small dog breeds.

2022 A large genetic study finds that there are 10 lineages of domestic dog and behavioural data suggests dogs within a lineage share certain traits. The lineages are retriever, terrier, herder, sighthound, dingo, Asian spitz, African and Middle Eastern spitz, sled, scenthound and pointer-spaniel.

DOGS AND AGEING: IS THE OLD CLICHÉ ACCURATE?

Does your dog really have seven birthdays for every one of yours?

The old cliché is that every year of a dog's life is equivalent to seven human years. In other words, a five-year-old dog is like a 35-year-old human. But it's not so simple. The rate at which dogs develop is different than for humans, and the dog's size and breed make a big difference to its lifespan.

Humans take 18 years to reach adulthood, but puppies are only pups for six to nine months (depending on the size and breed). Dogs typically undergo puberty between six months to a year, so that's their teenage phase. Then they count as young adults until they get to three to four years.

The American Animal Hospitals Association considers the last 25 per cent of a dog's life to be when they're old. Typically this is assumed to be around seven years of age, although it varies based on the breed (between five and ten years, say). With a human life expectancy of almost 81 in the UK, that would put a seven-year-old dog at about 61 human years.

If you're wondering about those breeds like the Great Dane that have short lifespans, it's been suggested that since research shows they're not 'aged' in terms of their behaviour or neurology when they die, these dogs sadly don't get to reach old age.

Then there's the differing lifespan of different breeds or mixes to take into account. A recent study of almost 2 million dogs who are clients of over 1,000 vet clinics in the US found the life expectancy of a dog when they're born is 12.69 years. This is a little bit higher than an earlier study in the UK, which put it at 11.23 years, and a bit lower than another US study, which found it was 15.4 years.

But it depends. Female dogs live slightly longer than male dogs. Small dogs live quite a bit longer than big dogs – small dogs for 16.2 years and giant dogs for 12 years according to one study. In general, mixed-breed dogs live a little longer than pedigrees, but some purebred dogs have long lifespans (chihuahuas, shih tzus and dachshunds were the longest-lived breeds in one study).

All of this tells us that a one-year-old dog is maybe the equivalent of an 18-year-old human, and perhaps after that, the 1:7 ratio makes more sense. Another line of research takes a biological approach instead. As we age, there are epigenetic changes to DNA as a result of a process called methylation. Scientists looked at these changes in the nucleic acid (called methylomes) of 104 labradors and compared them with those of humans. The relationship was not linear.

"A LONGER LIFE IS ASSOCIATED WITH YOUR DOG BEING A HEALTHY WEIGHT"

The results give us a different calculator: to find the human equivalent of a dog's age, take the log of that age, multiply by 16, and then add 31. It works best at either end of the lifespan and not quite so well for some of the middle years. Based on the epigenome, these scientists say an eight-week-old puppy is equivalent to a nine-month-old baby, and a 12-year-old dog is roughly equivalent to a 70-year-old person. They also made a chart that maps labrador age onto human age. It shows a one-year-old dog as

being equivalent to a 30-year-old human; a two-year-old dog as just over 40; a dog at seven as equivalent to a 60-year-old person; and a 14-year-old dog at around 80 in human terms. Of course, these results will vary for other dogs.

If this is starting to sound a bit depressing because your dog is older than you thought, take heart. One large study shows that a longer life is associated with your dog being a healthy weight, so keeping an eye on their weight will help (ask your veterinarian for advice).

For example, a normal-weight labrador lives 13.6 years if female and 13.3 if male, but if overweight that drops to 13.0 and 12.7 respectively. A normal weight yorkshire terrier lives 15.5 years (female) or 16.2 (male), but that drops to 13.5 or 13.7, respectively, if overweight. Dental cleanings are also linked to a longer lifespan, but it's not clear if this reflects better general health care or is specific to dental care.

So calculating a dog's age in human terms is more complicated than you might think, with the weeks and months of puppydom counting for a lot, even though they're over in a flash.

CRATES FOR DOGS: GOOD OR BAD?

Crates generally aren't needed. There may be times in your dog's life when they need to be confined (at the vet's after surgery, for example) and then it can help if they're already crate-trained. Crates can be used to transport your dog and can help with house training. But you can't shove a dog in a crate and expect them to like it – it takes training. A crate with the door always open can become a safe space for your dog to relax. But don't leave your dog in a crate all day while you're at work – they need space to move around.

GETTY IMAGES, REPLIKA

DRY VS WET VS RAW: WHAT DO DOGS REALLY NEED FOR THEIR DIET?

Sure, your dog may want what you're eating, whether it's a biscuit dunked in tea or spaghetti bolognese, but what does it need to eat in order to stay healthy?

There are so many options for dog food, it can be hard to know what to choose. Our choices are often shaped by cultural beliefs – after all, dogs are family members, so it's no surprise we think carefully about what to feed them.

Don't be swayed by marketing, though; dogs are not wolves. Dogs are omnivores, meaning they can eat food from both animals and plants. It sent ripples through the dog community when scientists comparing dog and wolf genes discovered that domestic dogs have 4-30 copies of a gene for amylase, a protein involved in starch digestion, depending on breed; wolves only have two copies of it. It was a surprise finding and it showed that dogs have gained the ability to digest starchy foods such as potatoes and grains.

So how do you pick something that will work for you and your dog? A lot of words on labels ('human-grade' or 'holistic') don't necessarily mean much. Dr Deborah Linder, a board-certified veterinary nutritionist at Cummings School of Veterinary Medicine at Tufts University, says, "Look for a nutritional adequacy statement on the pet food label that says if the food is complete and balanced, and what life stage it's appropriate for. There are growth/gestation and adult guidelines. Interestingly, however, there are no senior nutrition guidelines – that's just a marketing term because every pet needs something different as they age."

The World Small Animal Veterinary Association (WSAVA) suggests some questions to ask when researching foods, including what the company's reputation is like, whether they have a veterinary nutritionist on their team and what their quality control measures are.

As for raw food, the WSAVA says that there are risks because bacteria can be shed in the dog's stool without them showing any signs of illness; this may especially be of concern if anyone in your household is particularly vulnerable. They also say that bones shouldn't be included in raw food due to the risks of damage to your dog's teeth and of obstruction.

Any food that says it's 'supplemental' is unsuitable as the main diet; it's more for use as a treat. Of course, we all like to give treats. →

→ Dr Linder says, "Make sure 90 per cent of your pet's diet comes from a complete and balanced food, and 10 per cent of daily calories can come from treats or other food items." If you're looking for ideas for low-calorie treats or special diets, she and her colleagues have some great information on their Petfoodology blog (vetnutrition.tufts.edu/petfoodology).

The American Animal Hospitals Association says that grains in dog food can help to make it complete and balanced. Back in 2018, concerns were raised that some non-conventional diets (including grain-free) were associated with a heart issue in dogs called dilated cardiomyopathy. More research is needed, though. Meanwhile, if pulses are in the top 10 items on the ingredients list, some dogs might be at risk, according to Petfoodology.

When a dog is on a special diet, it can be a challenge finding training treats. Ingredients from their food can often work, and another great choice would be the canned version of the special diet. It can get messy using wet food in dog training, but you can use a spoon to put dollops of it in a bowl, or mix it with water and put it in a tube for your dog to lick from. If in doubt, ask your veterinarian if the food you've picked is right for your dog.

It's not just about what we feed our dogs, but also how we feed them. Dogs like to work for their food (contrafreeloading). These days a wide range of feeding enrichment activities are available, from toys to snuffle mats, balls and slow feeders. Scatter feeding, scent games, and home-made food puzzle toys are other options. These are not just for treats, but can be used to feed the dog's regular meals and provide cognitive enrichment too.

ARE WE DUMBING DOGS DOWN?

In a way, we've been dumbing dogs down since domestication began. We've changed them to make them cute and/or useful, so they're no longer the same as their wild ancestors. One of the key differences is that the sensitive period – when young pups are learning about the world – starts later in dog puppies, once all their senses are working; but in wolves it begins at two weeks, when they're still deaf and blind, and can only smell the world. So dog puppies learn to be sociable, less fearful and to ask us for help, and, in turn, may need us to care for them.

ALAMY X2, GETTY IMAGES

HOW TO UPGRADE YOUR DOG'S LIFE

A steak? A permanent place on the sofa? On open car window to lean out of during a long drive? What sorts of things are most likely to make your dog jump for joy?

My dog Pepper is an easy-going senior who loves bedtime. I'm sure his treat is part of it, but he also likes us all settling down for the night. He loves short walks, during which he gets to sniff a lot. And he's thrilled to see the horse that lives in a field nearby (he used to be afraid of horses, so this still means extra treats). Lots of dogs would like these things, but they're Pepper's favourites. When we think about how to upgrade a dog's life, we can take what we know is important for dogs in general, and then tailor it to our individual dog's likes.

1. Sniffs The general rule of enrichment is that it should involve the animal's most important sense. For dogs, that's smell. Dogs who do scentwork are more optimistic than those who engage in other activities that involve rewards. This was shown in research published in *Applied Animal Behaviour Science*, where scientists assigned dogs to a two-week group class, with homework in either scentwork or heelwork, and had them do a judgment bias test before and →

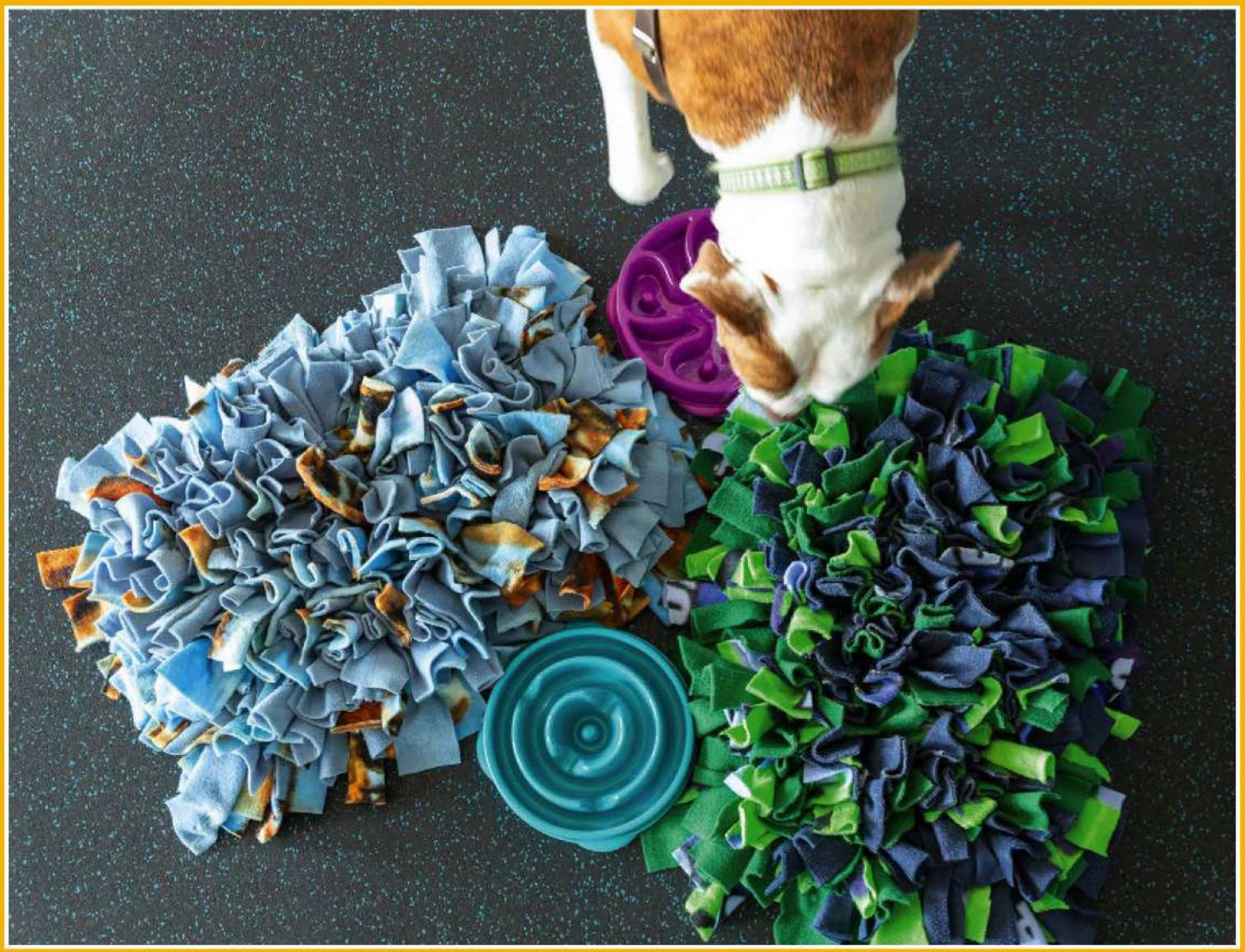
→ after. The test sees how quickly dogs respond to an ambiguous bowl placed between locations they know either always or never contain food (the idea is that an optimistic dog will expect food and get there sooner).

For off-lead walks let dogs use their noses. For on-lead walks, slow down and let them sniff, even if it makes the walk longer. You could also try: scattering treats in a safe spot of grass and letting your dog use her nose to find them; getting or making a snuffle mat (a rug with long, thick pile to hide treats in); hiding treats around the house when your dog isn't looking; or taking scentwork classes, which are suitable even for reactive dogs that may overreact to certain stimuli or situations in a way that's often confused with aggression.

2. Treats Improve the rewards you're using in training. Using food as positive reinforcement is the best way to train a dog, but don't make the mistake of using kibble. Try a variety of treats and human foods like chicken, roast beef or cheese.

Scientists have shown that dogs are speedier to get to a bowl they know contains a piece of sausage than to one containing a piece of kibble. So don't think they aren't paying attention to the rewards you're using. Although some dogs have a single preferred treat, most like variety over time. Play, such as a quick game of tug, can be a great reward for some dogs.

If you're not using reward-based training, it's time to make the change. Leash jerks, yelling, prong and shock collars are all associated with risks to your dog's welfare.



3. Playtime If your dog likes other dogs, find opportunities for dog-dog play, maybe with specific doggy friends. Play is important for dogs, especially when they're young. Ideally, puppies will have carefully supervised play sessions in puppy class. Play helps puppies learn how to bite gently and develop other motor skills.

Play fulfils important social functions too. If you watch dogs playing, you'll notice some of the signs like a bounce in their step, a gorgeous play face expression and a 'play bow' (front legs down on the ground, bum up in the air). You'll also see changes in activities, as the dog that was being chased becomes the one doing the chasing, and so on. Older dogs play less, are less tolerant of full-on play and may prefer to just hang out with another dog rather than wrestle or chase.

If your dog doesn't like unknown dogs, stick to meeting dogs that you know your dog already likes. And if they don't like other dogs at all, make more time for play with you instead – also a great way to fulfill their need for play.

4. Safety Give your dog a safe space to go when they want to chill out and relax. It could be a dog bed in a quiet spot or a crate with the door always open. It's especially important in homes with children or if your dog is shy or fearful. Make sure everyone in the household knows the rule: the dog can come and go from their spot as they wish and no one will bother them. If you need to get them out of their safe space, don't go to them; instead, call them over to you.

"PLAY HELPS PUPPIES LEARN HOW TO BITE GENTLY AND DEVELOP OTHER MOTOR SKILLS"

5. Snoozes Dogs sleep a lot, so it's worth investing in good dog beds. They'll no doubt like your sofa and bed too, so ignore the old myths and decide for yourself if you want them on the furniture. Old dogs sleep more than adults and may suffer from issues like arthritis, so may need a bed that's lower to the ground (easier to step into) and steps or a ramp to access furniture.

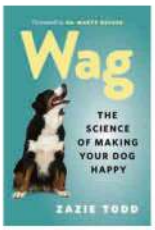
6. Fun Do more things with your dog that you both enjoy. Do they like fetch, tug or chasing games? They might like to play with the flirt pole (like a cat's wand toy, but for dogs) as it engages their predatory instincts.

Does your dog prefer a walk through the forest or a visit to a park with a pond they can splash in? Maybe they would simply like to accompany you on errands or cuddle on the sofa while watching TV. Preferences can be individual and we can't assume a dog likes something, so think carefully about what gets your dog's tail wagging. Engaging in joint activities and spending time together is one way to improve the dog-human bond. SF

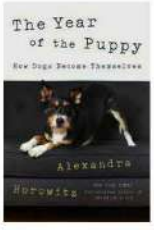
GETTY IMAGES X2

DO LEADS MAKE DOGS MORE TENSE?

A lead constrains your dog's movement and that can make them more tense, especially if an off-lead dog runs up to them – they don't have freedom to move away. The lead can also interfere with their body language and their ability to read other dogs' body language (they can't move to get a better view). Dogs on leads are less likely to interact with other dogs and sniff less than dogs off lead. What you do with the lead matters too: don't jerk the lead or attach it to a shock, prong or choke collar as this can cause stress and is bad for their welfare.



by **DR ZAZIE TODD**
Zazie is an animal behaviour expert and the author of Wag: The Science of Making Your Dog Happy.



by **PROF ALEXANDRA HOROWITZ**
Alexandra heads the Dog Cognition Lab at Barnard College, Columbia University Her new book, The Year of the Puppy: How Dogs Become Themselves *is out in September.*

Q&A

Email your questions to questions@sciencefocus.com or submit them on Twitter at @sciencefocus

YOUR QUESTIONS ANSWERED

ALBIE HEWITT, RIPON

HOW RADIOACTIVE IS MY HOUSE? (DO I NEED TO WORRY?)

Pedantically, we could say that your house is literally bathed in radiation day and night, since visible light is radiation, and so are the infrared wavelengths coming from your radiators and the 2.4GHz frequency radio waves from your home Wi-Fi and mobile phone. But what you're probably referring to is *ionising* radiation – the kind powerful enough to knock electrons out of atoms and thereby cause cancer and, at very high doses, radiation poisoning and burns.

Old-fashioned cathode-ray tube monitors used to be a low-level source of ionising X-rays, but these have virtually all been replaced with flat-screen monitors, which don't emit X-rays. So the remaining domestic sources of radiation are mostly things that contain small amounts of radioactive elements. Bananas, for example, contain enough of the isotope potassium-40 that eating one gives you 0.0001 millisieverts (mSv) – roughly the same radiation dose as living within 80km (50 miles) of a nuclear power plant (in other words, virtually none).

Brazil nuts are about five times more radioactive as a result of the very deep roots of Brazil nut trees that concentrate radioactive radium in the soil. But eating two or three Brazil nuts a day is still perfectly safe. Smoking is already very bad for your health of course, but it's made slightly worse by the fact that the fertilisers used on tobacco plants contain radioactive radium, lead and polonium, making a single cigarette as radioactive as seven bananas.

Smoke detectors contain tiny amounts of the isotope americium-241. Americium emits radiation by alpha decay, which can be completely blocked by as little as a sheet of paper so it never escapes the smoke detector case and would only be a health hazard if you ate it. Speaking of eating, some ceramic plates and cups made between the 1930s and 1970s used uranium oxide glazes. Eating or drinking from these was roughly equivalent to eating one banana an hour.

DR HELEN PILCHER
Biologist and science writer

PETE LAWRENCE
Astronomy expert

HAYLEY BENNETT
Science writer

DR EMMA DAVIES
Science writer

DR CHRISTIAN JARRETT
Psychologist and author

DR NISH MANEK
GP and medical expert

LUIS VILLAZON
Science and technology writer

But if you mean how radioactive is *your* house, specifically (as in the building in which you reside), well that depends on where you live. If you live in the Southwest of England, then the largest source of the radiation in your home by far is the granite beneath it. Granite naturally contains some uranium, and this undergoes radioactive decay to form radium and then radon gas. This gas seeps slowly into the air and, because it emits alpha radiation, can increase the risk of lung cancer if the concentration is allowed to rise.

In parts of the UK with lots of granite, such as Cornwall, the background dose can be 7.8mSv per year (78,000 bananas). The health risks of radon in the home can be greatly reduced by improving ventilation, particularly in basements, to prevent the radon gas concentration from building up.

Radiation dose also increases with altitude, because there's less atmosphere between you and the cosmic rays bombarding Earth from space. Each day you spend in Denver, Colorado (altitude 1,600m/5,200ft) gives you

"IF YOU LIVE IN THE SOUTHWEST OF ENGLAND, THEN THE LARGEST SOURCE OF THE RADIATION IN YOUR HOME BY FAR IS THE GRANITE BENEATH IT"

an extra 12 bananas worth of radiation, while a single transatlantic plane flight will give you about 0.04mSv of radiation (400 bananas).

If you're lucky enough to be one of the astronauts that calls the International Space Station home, a six-month stay up there would add another 80mSv. Which is quite a lot, but still better for your health than eating 800,000 bananas! ***LV***

CHRISTIAN DAVIES, VIA EMAIL

WHY IS SALTY FOOD SO SATISFYING?

Salty foods are often highly processed and, with the help of other ingredients, such as carbohydrates and fats, are frustratingly satisfying to eat.

In small doses, salt acts as a flavour enhancer, reducing bitterness and increasing sweetness. Sodium in table salt (sodium chloride) has essential functions in the body, but we excrete it constantly, so need to consume it in small amounts in food. In an effort to cut harmful consumption, researchers are working on proteins designed to taste salty or enhance salt taste. But it's easier said than done – while some of the tongue's taste buds are designed to sense sodium ions, the exact mechanism isn't fully understood. ***ED***

MARION THOMAS, VIA EMAIL

ARE THERE REALLY WALLABIES LIVING IN THE UK?

Yes! It's thought the populations stem mainly from animals escaped from zoos and private collections. In 2020, researchers from University College Dublin and the University of South Wales mapped 95 confirmed wallaby sightings in a study published in *Ecology & Evolution*. The sightings, recorded between 2008-2018, were mainly in the south of England and included two females with joeys in their pouches, suggesting wild breeding. When asked in May, one of the study's authors, Dr Anthony Caravaggi, told *BBC Science Focus* he had received 10 reports of wallaby sightings already in 2023 and was looking to fund a fresh study on them. ***HB***

GETTY IMAGES, ALAMY ILLUSTRATIONS: JOE WALDRON

NATURE'S WEIRDEST CREATURES

SHEEPSHEAD FISH

Someone slap a lawsuit on the dentist who fitted this fish with the freakishly human teeth... What's that you say? Evolution did this. By natural selection? What was it thinking!

The sheepshead fish, aka the lovechild of Billy Bass and my granny's dentures, is a scaly, sparkly swimmer that can be found in the shallow waters of the western Atlantic, from Nova Scotia to Brazil. It's a euryhaline species, which means it can tolerate a wide range of salinity. While the fish usually lives in coastal waters and estuaries, they sometimes head to freshwater to find warmth in winter. In days gone by, the fish could be spotted in Brooklyn's Sheepshead Bay, which was named after it, but then the Bay became polluted and the fish disappeared.

No one knows exactly why it's called the 'sheepshead' fish, when its teeth are clearly the main event, but some say that its blunt snout and almost horizontal mouth are indeed sheep-like. Its grey and black stripes do, however, lend themselves to its alternative moniker of the convict fish. Put one in jail next to a prisoner in a striped uniform and it shouldn't look like a fish out of water.

Freshly hatched sheepshead fish are tiny and toothless. They dine on soft foods, such as marine worms and plant matter. Their teeth start to come through as they approach 5cm (2in) in length, and from then on, the fish start to tackle more robust, shelled prey, such as barnacles, clams, crabs and oysters. Adult sheepshead fish, which grow up to 75cm (30in) long, have three rows of teeth in their upper jaw, and two rows lining their bottom jaw. These include chisel-shaped incisor-like teeth at the front, and flatter molars and rounded grinders towards the back. All of which are coated in a hard, enamel-like substance, laid on top of a calcified dentin interior.

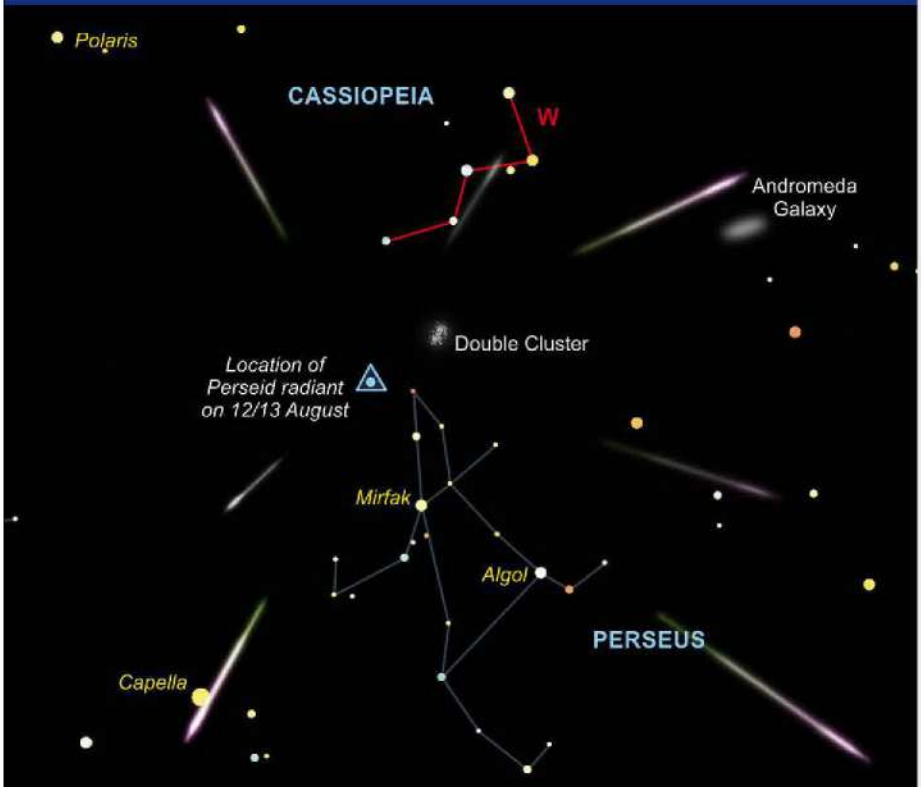
This seemingly motley collection of gnashers, which is not so different to our own, is an adaptation to the fish's omnivorous diet. Evolution has selected for this arrangement because it enables the fish to bite, crush and grind, and exploit a rich variety of food sources. The sheepshead fish is known to eat more than a hundred different species. This is part of the reason why it has been so successful.

Another reason is that it has relatively little meat on its body and sharp dorsal spines, which make it difficult to fillet. Although the meat is sweet, with a flaky, tender texture, commercial fisheries have historically focussed on other, more economically viable species, such as the red drum. This could change, however. Although the sheepshead fish is relatively plentiful now, as stocks of red drum and other local fish decline, there are concerns that the toothy icon could be next.

In the meantime, don't worry if you encounter one. Sheepshead fish don't bite (unless you're a clam or an oyster), but they do have a smile that would melt the heart of even the most indifferent orthodontist. ***HP***

GETTY IMAGES, ALAMY ILLUSTRATION: PETE LAWRENCE

ASTRONOMY FOR BEGINNERS



SPLENDID PERSEIDS

WHEN: EARLY-LATE AUGUST

The Perseid meteor shower shows activity from mid-July through to late August. Generally the meteor rate is low, but between 10-16 August, rates are higher, reaching a peak in the early hours of 13 August.

Several factors affect the quality of a display. Sky clarity is one and this depends on light pollution, weather and the Moon. The Moon won't interfere much this year, so if the weather looks good, it's worth planning a trip to a dark location if you have light polluted skies.

Another factor is radiant altitude. A meteor shower occurs when Earth passes through the fine dust spread around a comet's orbit, in this case 109P/Swift-Tuttle. The typically sand-grain sized particles (meteoroids) are in parallel orbits around the Sun. As they enter our atmosphere, perspective makes it look as if they emerge from the same area of sky: the shower radiant. If the radiant is low, the number of meteors seen will also be low. The Perseid radiant climbs to its highest altitude as dawn begins around 3:20am BST from the centre of the UK.

After local midnight (1am BST/ midnight GMT), the Earth turns to encounter meteoroids head on. This increases the impact energy, with more and brighter trails being seen.

To enjoy this wonderful shower, find a dark location away from stray lights. Give yourself at least 20 minutes to adapt your eyes and make yourself comfortable on a sun lounger. Look roughly two-thirds up the sky (60°) in any direction and wait. If you can't decide on a direction, south and southeast have some interesting constellations to look at during lulls. *PL*

by PETE LAWRENCE
(@Avertedvision)
Pete is an astronomy expert and presenter on BBC's The Sky at Night

WATCH *THE SKY AT NIGHT* ON BBC FOUR AND BBC IPLAYER
BBC FOUR

ALEXA RHODES, WINCHESTER

SHOULD I EAT DESSERT WITH BREAKFAST TO HELP ME DIET?

It's hard to say whether devouring a dessert at breakfast actually helps with weight loss. The most reported research comes from a team led by endocrinologist Prof Daniela Jakubowicz at Tel Aviv University in Israel. In 2012, her team published a study of 193 people on a calorie-controlled diet who consumed either a low-carbohydrate breakfast or one with high protein and high carbohydrate, including a sweet treat such as a piece of cake or a doughnut.

After 16 weeks, the low-carb group started to regain weight while the breakfast treat group lost a few more kilos. The scientists reported that people in the treat group were more likely to stick to their diets, possibly because the foods lost some of their 'reward value'. The morning dessert also appeared to reduce levels of the hunger hormone ghrelin and so cut food cravings. In a later book, *The Big Breakfast Diet*, Jakubowicz explained that the hormones that control appetite, energy and metabolism vary naturally around the clock. She prescribed an early protein-packed breakfast with a sweet treat, followed by a carb-free lunch and dinner with no sweets.

Testing whether such diets work is difficult because people tend to lie about what they eat and trials don't generally last long enough to see true results. Although there is some evidence that consuming more of a calorie-controlled diet early in the day results in greater weight loss, according to a 2022 review by Isabel Young and colleagues at the University of Sydney in Australia. The human body has 'metabolically evolved' to consume more calories earlier in the day, they said.

While a central circadian rhythm is responsible for regulating sleep, body temperature and melatonin production, peripheral rhythms cover metabolic hormones such as insulin and ghrelin. Eating more earlier in the day may help to synchronise the circadian rhythms, so that we feel more in tune with ourselves, they suggested. They also highlighted data showing improvements in blood sugar levels and cholesterol with morning eating.

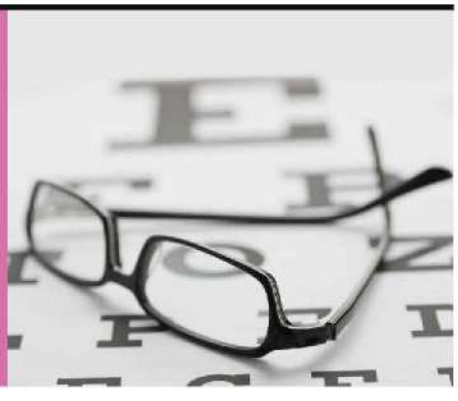
Meanwhile, a UK review led by Dr Suzana Almoosawi at the University of Newcastle concluded that we still don't understand whether energy should be distributed equally across the day, or whether breakfast should provide most of it. Evidence from human studies appears to indicate that it's harder to feel full as the day goes on, potentially hinting at a need to consume a greater proportion of energy earlier in the day, they said.

When they analysed data from the UK's official National Diet and Nutrition Survey, they found that high-carb eaters, who also consumed more between 6am and 9am than moderate- or low-carb eaters, appeared to be the healthiest. But they pointed out that those on low-carb diets may simply have turned to fat or alcohol as replacements. Which just goes to show how difficult it is to study human diet. ***ED***

MILLY O'NEILL, CANTERBURY

HOW DO VARIFOCAL GLASSES WORK?

Varifocals are lenses that allow you to see close-up, far away and somewhere in between, all through the same pair of glasses. Originally known as Varilux lenses, they were invented by engineer Bernard Maitenaz at a French spectacle company in 1959. Modern varifocals combine different prescriptions within a single lens, usually with near vision at the bottom, distance vision at the top and intermediate vision in the middle. While in bifocal lenses, the change between the near vision and distance vision prescriptions is clear-cut, in varifocals, there's more of a smooth transition, which gives the wearer a more seamless viewing experience. ***HB***



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TYRONE CHASE, VIA EMAIL

WHY DOES MY DOG GIVE ME SIDE EYE?

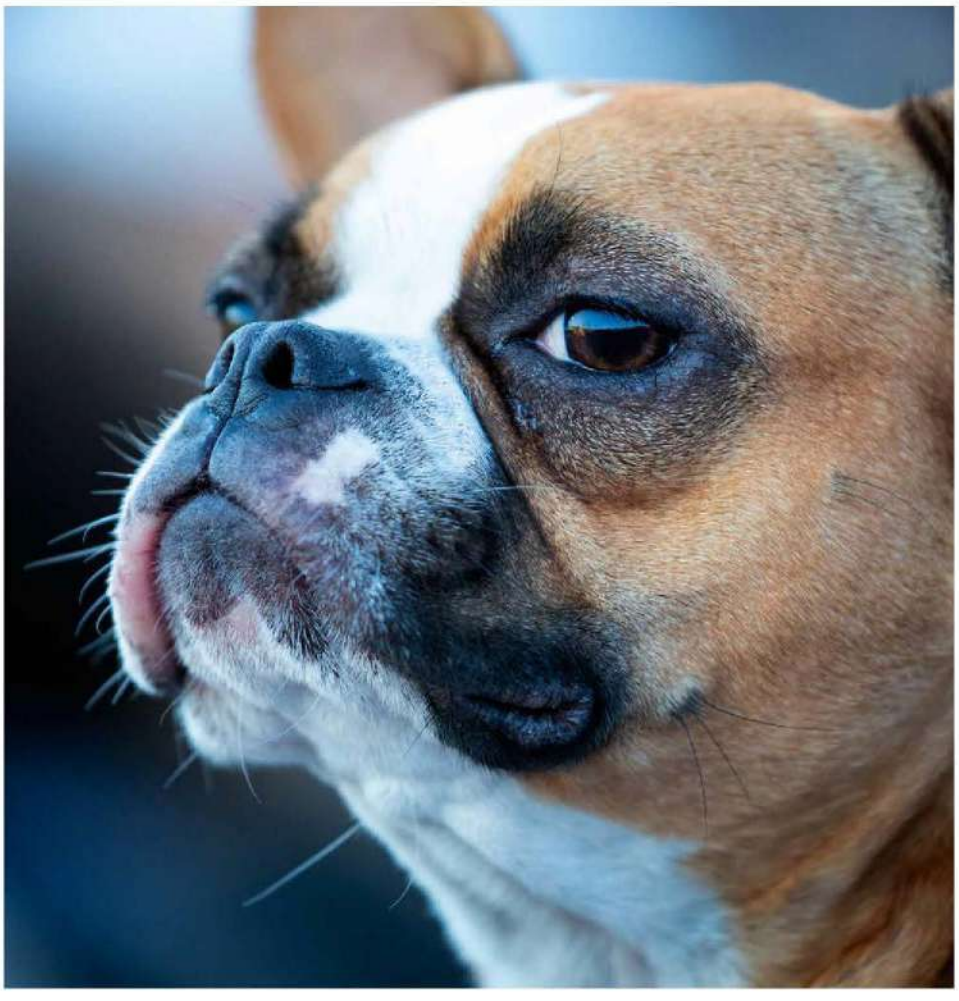
Dog side eye, aka 'the shady gaze', is the subject of many seemingly humorous memes. But this canine characteristic is often more loaded than the videos suggest.

Humans give side eye as an expression of doubt, scorn or disapproval, which is why it's so amusing to see in dogs. It occurs when the coloured part of the eye, known as the iris, swivels to the side, to reveal more of the white part, known as the sclera. In dogs, this charismatic look is often accompanied by other non-verbal gestures, such as flattened ears and a slight turning away of the head. This gives animal behaviourists some insight into its meaning.

Dogs give side eye for various reasons. When the cocker spaniel next door encounters our cat, for example, her sardonic look of 'oh, really?' belies the fact that she's actually anxious (and with good reason: our cat is a nightmare). She makes the same expression when our dog is guarding a desirable treat. In this case, the avoidance of direct eye contact is her way of saying: 'If I'm not looking at you, I can't possibly be plotting theft.' It works too. She spots the instant that our dog drops his guard and the treat is in her belly before you can so much as shout: 'Stop! Thief!'

In other dogs in other instances, 'half-moon eye' may also be used to convey different emotions, such as feeling protective or territorial.

Dogs owe this expressive capability to the whites of their eyes, which are an anomaly in the animal kingdom. Most animals don't have white sclerae. It's thought that, during domestication, our ancestors may have inadvertently selected for dogs with white sclera, because it aided communication between our two species. The funny videos were an unexpected by-product! ***HP***



WILL OLIVER, EXETER

WHY DO I GO RED WHEN I'M EMBARRASSED OR HAVE BEEN DRINKING?

Blushing, or turning red in the face, is a fascinating physiological response that occurs in certain situations, such as embarrassment or alcohol consumption.

It happens because when we feel embarrassed or are in socially awkward situations, our body's stress response is triggered. This response involves the release of adrenaline, which causes blood vessels in our skin to dilate, allowing more blood to flow through them. The increased blood flow leads to the reddening of the face, giving rise to the characteristic blush.

What purpose does blushing serve? While the utility of blushing continues to remain elusive, it may have some social upsides. Blushing likely evolved as a social signal to communicate our emotional state to others – for example by helping to acknowledge a mistake, defusing the tension in a situation.

Interestingly, alcohol consumption can also trigger facial redness in some people. When we drink alcohol, our bodies metabolise it into a substance called acetaldehyde. This compound can cause blood vessels to expand, resulting in increased blood flow to the skin. As a result, our face can turn red, known as the 'alcohol flush reaction'.

The alcohol flush reaction is more common among certain populations, particularly individuals of East Asian descent. This is because they tend to have lower levels of an enzyme called aldehyde dehydrogenase, which is responsible for breaking down acetaldehyde. When acetaldehyde builds up in the body, it leads to more intense facial flushing.

Unfortunately, both of these blushing mechanisms are outside of our control, so you just have to grin and bear it! ***NM***

What a dream!

Being mindful of good sleep habits can help to prepare you for a restful night. Do you have good sleep hygiene?

Set up a good routine
A regular schedule around bedtime can get your body and brain ready to power down.

Create a sleep sanctuary
Where you sleep should be a quiet, dark space, with a temperature of around 16-18°C (60-64°F).

Do some daily exercise
Regular exercise will tire you out and help you to relax, but avoid anything too energetic before bed.

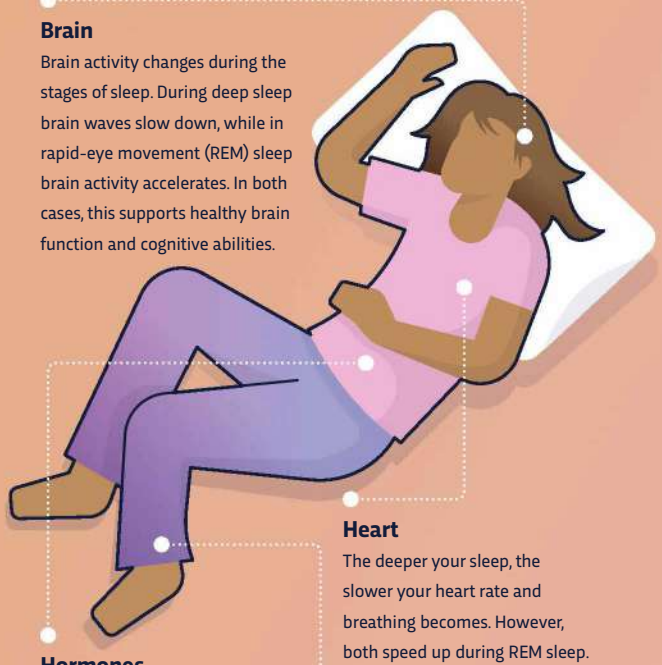
The A to Z of Sleep

Infographic by James Round

There are few human experiences as universal as sleep. Not only does it define the shape of our days, it's an essential process that keeps us alive. It's also a connection we share with all other life on Earth, and while sleep has a number of interesting and unusual features across the animal kingdom, scientists have never discovered a truly sleepless species. Despite its integral role in our lives, there's a lot of mysteries left to uncover about what happens when we close our eyes at night. One thing we do know for sure is that sleep can impact almost every facet of our health and well-being. In fact, it might just be the most important part of your day.

Sleep and the body

When you're asleep, almost every part of your body experiences notable changes. The biological role of sleep still isn't fully understood, however by looking at what happens to different parts of the body when we're asleep, we can better interpret its functions and purpose.



Brain

Brain activity changes during the stages of sleep. During deep sleep brain waves slow down, while in rapid-eye movement (REM) sleep brain activity accelerates. In both cases, this supports healthy brain function and cognitive abilities.

Heart

The deeper your sleep, the slower your heart rate and breathing becomes. However, both speed up during REM sleep.

Muscles

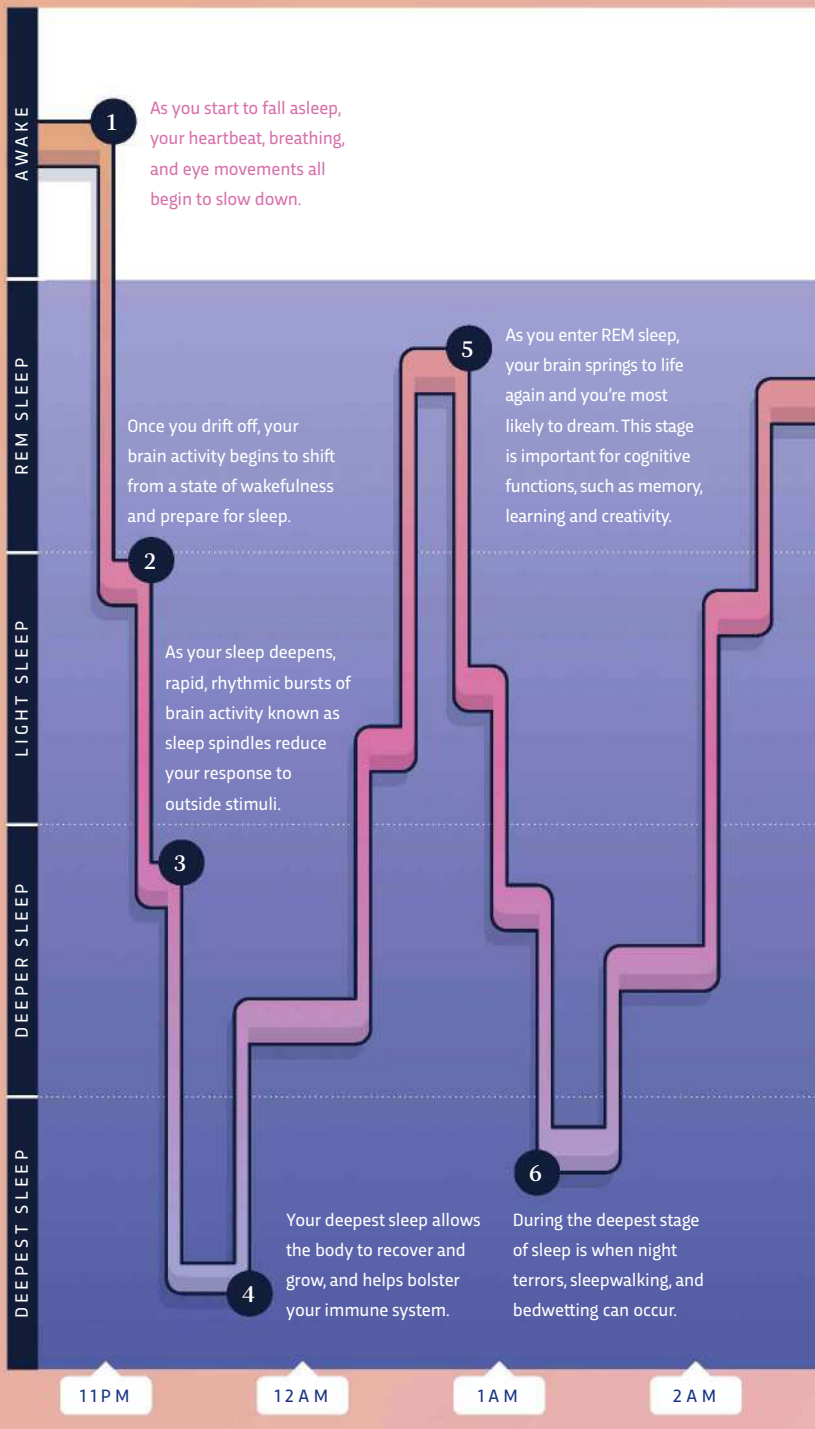
During sleep your muscles relax, apart from those with respiratory functions and your eye muscles, which twitch as your dream.

Hormones

Sleep helps regulate hormone production, including: those that support bone and muscle development; cortisol, which manages stress levels; and leptin and ghrelin, which control appetite.

The sleep cycle

When you fall asleep you enter into a process known as the sleep cycle. This is made up of four stages, each associated with specific brain activity but, more broadly, you cycle repeatedly through two types of sleep: REM (rapid-eye movement) sleep and non-REM sleep.


AWAKE
REM SLEEP
LIGHT SLEEP
DEEPER SLEEP
DEEPEST SLEEP
1
As you start to fall asleep, your heartbeat, breathing, and eye movements all begin to slow down.
2
Once you drift off, your brain activity begins to shift from a state of wakefulness and prepare for sleep.
3
As your sleep deepens, rapid, rhythmic bursts of brain activity known as sleep spindles reduce your response to outside stimuli.
4
Your deepest sleep allows the body to recover and grow, and helps bolster your immune system.
5
As you enter REM sleep, your brain springs to life again and you're most likely to dream. This stage is important for cognitive functions, such as memory, learning and creativity.
6
During the deepest stage of sleep is when night terrors, sleepwalking, and bedwetting can occur.
11 PM
12 AM
1 AM
2 AM

SOURCES NHS, CDC, National Library of Medicine, Sleep Foundation, Philips Global Sleep Survey.

Ahh, nightmare!

As well as forming good habits that support your sleep, it's also worth knowing a few things to avoid...

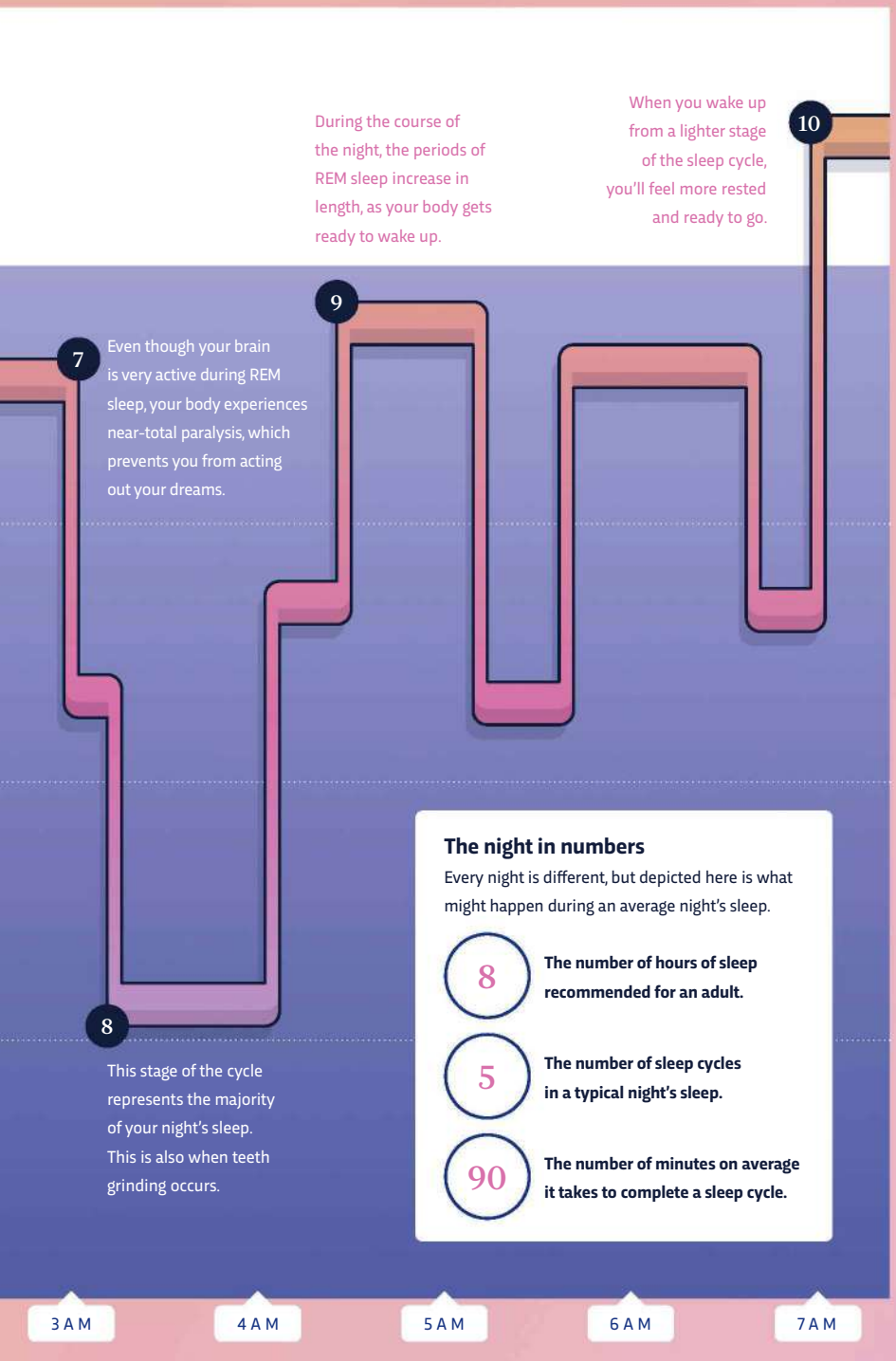
Put the phone down
The light from electronic devices suppresses a hormone that helps you feel ready for sleep.

Skip the stimulants
Alcohol, caffeine and nicotine before bed are all common causes of sleep problems.

Don't force it
If you're unable nod off, it's best to get up and do something relaxing to try and encourage sleep.

How long can a person go without sleep?

In 1986, Robert McDonald didn't sleep for over 453 hours, and set a world record in the process. Others have since claimed to have exceeded this, but Guinness World Records stopped monitoring the record in part because of the risks associated with sleep deprivation, which include irritability, paranoia, mood changes and even hallucinations.


10
During the course of the night, the periods of REM sleep increase in length, as your body gets ready to wake up.
When you wake up from a lighter stage of the sleep cycle, you'll feel more rested and ready to go.
9
7
Even though your brain is very active during REM sleep, your body experiences near-total paralysis, which prevents you from acting out your dreams.
8
This stage of the cycle represents the majority of your night's sleep. This is also when teeth grinding occurs.
3 A M
4 A M
5 A M
6 A M
7 A M

The night in numbers

Every night is different, but depicted here is what might happen during an average night's sleep.

8 — **The number of hours of sleep recommended for an adult.**

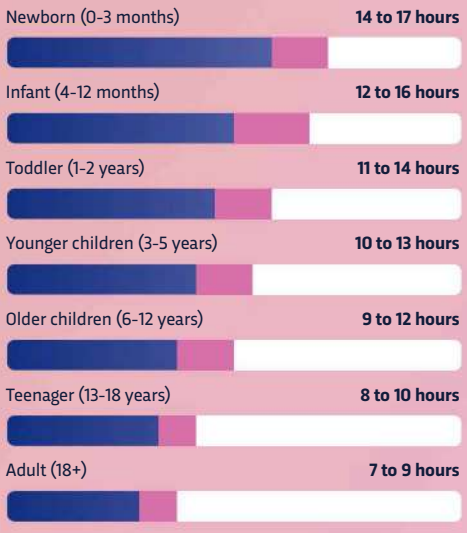
5 — **The number of sleep cycles in a typical night's sleep.**

90 — **The number of minutes on average it takes to complete a sleep cycle.**

How do you sleep at night?

Sleep is something that we all do, but the experience isn't the same for everyone. The way you sleep can vary based on a number of different factors...

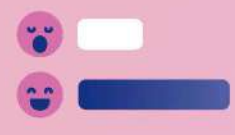
Your sleep needs change as you get older.


Newborn (0-3 months) 14 to 17 hours
Infant (4-12 months) 12 to 16 hours
Toddler (1-2 years) 11 to 14 hours
Younger children (3-5 years) 10 to 13 hours
Older children (6-12 years) 9 to 12 hours
Teenager (13-18 years) 8 to 10 hours
Adult (18+) 7 to 9 hours

In our distraction-filled world, a lot of people struggle to get a good night's sleep.

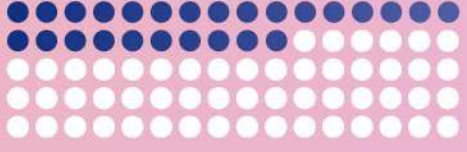
A 2021 survey revealed that on average only 55% of people were satisfied with their sleep. This figure varies around the world; in India it was 67%, whereas in France it was as low as 35%.

Meanwhile in the US, over one-third of adults sleep less than the recommended seven hours per night.



And you shouldn't underestimate the importance of sleep, it's a big part of your life!

We spend-one third of our lives either sleeping or attempting to do so. That means, if you live to be 80, you'll spend over 26 years of your life asleep.



DEAR DOCTOR

HOW DO I **STOP HICCUPING**? WHAT WILL ACTUALLY WORK?

Hiccups, those sudden and sometimes annoying contractions of the diaphragm, can be a perplexing phenomenon. During a hiccup your diaphragm contracts and, immediately after this, the top of your windpipe (your glottis) closes, making the typical 'hic' sound.

Hiccups can be annoying and inconvenient, but will usually pass on their own after a short time. People sometimes like to try things in the hope of speeding things up though. While there is no foolproof cure, several techniques have been suggested (although none of them have much of an evidence base)...

1 Breathing techniques Holding your breath for a short time apparently increases the level of carbon dioxide in your bloodstream, which may help reset your breathing pattern and stop the hiccups. Other breath-holding techniques, such as breathing into a paper bag or performing a modified Valsalva manoeuvre have also been suggested (the way to do this is by taking a deep breath in, then blocking your mouth and noise while pushing with your muscles as if to force the air out, as if you're straining on the toilet). These methods are based on the principle of altering the respiratory pattern and may help interrupt the hiccup reflex, but are not guaranteed to work.

2 Drinking water or swallowing granulated sugar Both of these remedies aim to interrupt the hiccup cycle by stimulating the vagus nerve, which plays a role in regulating the diaphragm contractions. While some people say these techniques do work, scientific evidence is, once again, limited.

3 Eating something sweet or sour Similar to drinking water or swallowing sugar, consuming something sweet or sour is believed to stimulate the vagus nerve and potentially halt hiccups. Again, the evidence supporting either the sweet or sour approach is anecdotal.

4 Distraction and relaxation Engaging in activities that divert your attention from your hiccuping or induce relaxation (such as counting backwards, focusing on your breathing or gently massaging the area around your diaphragm), may help interrupt the hiccup cycle. While these methods may not have a direct physiological effect, they can help shift your focus away from the hiccups.

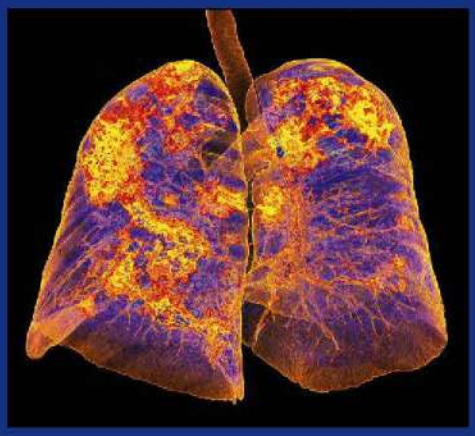
It's important to note that the remedies mentioned above have varying degrees of scientific evidence supporting their effectiveness. Most studies are based on anecdotal reports or small sample sizes, and there is a lack of robust research on hiccup cures.

Most of the time, ordinary bursts of hiccups will simply pass by themselves. The trick is in being prepared to wait for that to happen. That being said, most of the remedies suggested above are fairly harmless to try.

If you have found a particular technique that consistently works for you, it may be due, at least in part, to the placebo effect. We tend to find the things we believe in are more likely to work! *NM*

IZABELLA ACEVEDO, VIA EMAIL

BEFORE WE HAD LONG COVID, WAS THERE LONG SARS?

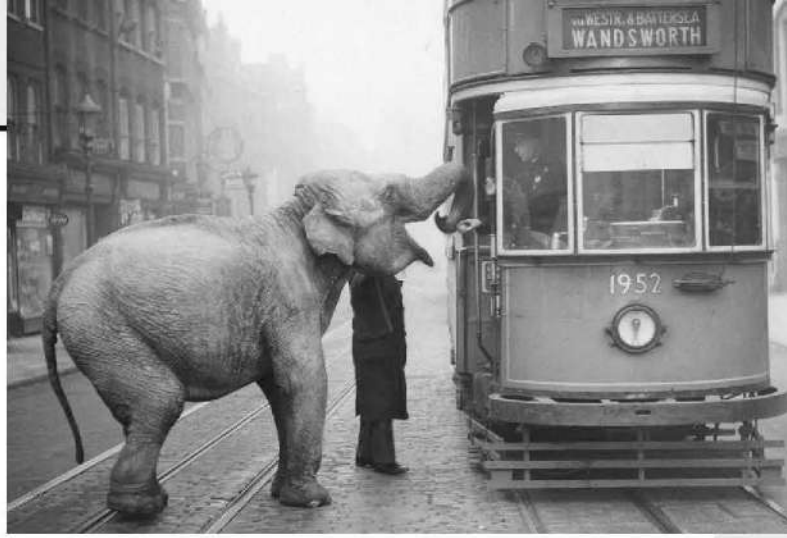


The SARS epidemic of 2002-2004, caused by the severe acute respiratory syndrome coronavirus (SARS-CoV), affected over 8,000 people globally. Research into the long-term effects of SARS has been done, although the number of studies and participants is limited compared to COVID-19. Some documented complications from SARS include reduced lung function, persistent cough and exercise intolerance. Some people also went on to experience physical weakness, fatigue and musculoskeletal issues.

However the term 'long SARS' hasn't gained the same recognition as 'long COVID'. The concept of long COVID refers to the persistent symptoms experienced by some people after recovering from COVID-19. The symptoms can range from fatigue, brain fog and shortness of breath to joint pain and organ dysfunction.

While long COVID has received a lot of attention and research, the term 'long SARS' isn't commonly used to describe similar long-term effects associated with SARS survivors. The SARS epidemic occurred over a decade before the COVID-19 pandemic and the research landscape has evolved significantly since then. The increased focus on long COVID has led to a greater recognition of the long-term effects of viral respiratory illnesses, and the need for further investigation into their mechanisms and potential treatments.

Continued research efforts are needed to better understand and support the health and well-being of people who have survived viral respiratory illnesses like SARS. For now, it's difficult to make the same comparison to long COVID, although research does suggest that people have experienced some long-term symptoms, particularly fatigue. ***NM***



MAX HOOPER, SOUTHAMPTON

ANEMOIA: WHY AM I NOSTALGIC FOR A TIME I DIDN'T KNOW OR A PLACE I'VE NEVER BEEN?

The term 'nostalgia' was coined by a Swiss doctor in the 17th century to describe the homesickness experienced by mercenaries fighting far from home (from the Greek 'nostos' – the desire to return home – and 'algos', meaning pain). That's not so different from how we use the term to refer to thinking fondly or wistfully of the past, such as places you've been or people you've known. In fact, psychologists have shown that nostalgia of this kind has various psychological benefits, such as countering feelings of loneliness or existential anxiety. But a yearning for a past that you never actually experienced is different (and has its own name, 'anemoia', according to the *Dictionary of Obscure Sorrows*).

Traditionally, psychologists thought of nostalgia as being based on a person's recollections of their own experiences, which makes it difficult to fit what you've described into their account. More recently, however, the philosopher Prof Felipe De Brigard at Duke University has proposed that nostalgia is broader, and includes your yearnings.

De Brigard was inspired by research on memory that's shown it's a creative process. When you recollect memories, it's not like you're looking up a recording of what happened, it's more like your brain creates a simulation of those past events. In this way, De Brigard argues that nostalgia can be based on memories – simulations of pleasant past experiences – but doesn't have to be. Given the role of imagination in memory, he says it's not a huge leap to propose that nostalgia can also be based on imagined positive past experiences.

This kind of imagination-based nostalgia is likely to be influenced by stories and propaganda about the past. So it's quite likely that you've read or heard rose-tinted accounts of historical periods or places. Based on those accounts, your mind creates a simulation of what those places or times would have been like and you then feel a yearning to experience them for yourself. De Brigard says this is more likely if you're feeling dissatisfied with your current situation.

You're far from the only one experiencing this kind of nostalgia and recently social psychologists and political scientists have started to wonder whether anemoia could be playing a part in the rise of populist movements, such as the 'Make America Great Again' movement in the US, or the Brexit campaigns in the UK.

Older populist voters might be inspired by conventional nostalgia, for times they really did experience (that's not to say their memories are necessarily accurate). But many young voters also seem to be susceptible to nostalgia-based propaganda and anemoia helps to make sense of this. Like you, they could be experiencing rose-tinted nostalgia for past places and times, especially if they're struggling in present circumstances. In turn, perhaps this attracts them to politicians who promise a return to the 'good old days' – even if those days are little more than a figment of the imagination. ***CJ***

QUESTION OF THE MONTH

AMY WEBSTER, AGE 15 VIA EMAIL

HOW DOES THE FITNESS APP ON MY PHONE KNOW HOW MANY STEPS I'VE TAKEN, ESPECIALLY IF IT'S IN MY BAG?

Your phone uses GPS to track distance travelled. But try disabling it and you'll notice that fitness apps will still give you step counts. They do this using your phone's built-in sensors, which usually include an accelerometer and a gyroscope. Accelerometers measure acceleration, while gyroscopes help track the direction your phone is pointing in, usually by measuring the movements of tiny components inside them that generate electric signals as they move. According to the experts, the best place to count steps is at the hip and so putting your phone in your pocket should provide a more accurate count than putting it in your bag.

A study published last year tried to verify the accuracy of smartphone apps for step-counting, comparing results from a medical-grade accelerometer worn on the hip to those from the WeRun app. 103 people used both at the same time, for three, week-long bouts of step-counting. The study showed the app overestimated the average daily step count of around 8,500 steps by close to 500 steps. ***HB***

WINNER

The winner of next issue's *Question of the Month* wins a **trio of hardback popular-science books**: *Life on Other Planets* by Dr Aomawa Shields; *Quantum Supremacy* by Michio Kaku; and *If Nietzsche Were a Narwhal* by Justin Gregg, worth over £65.

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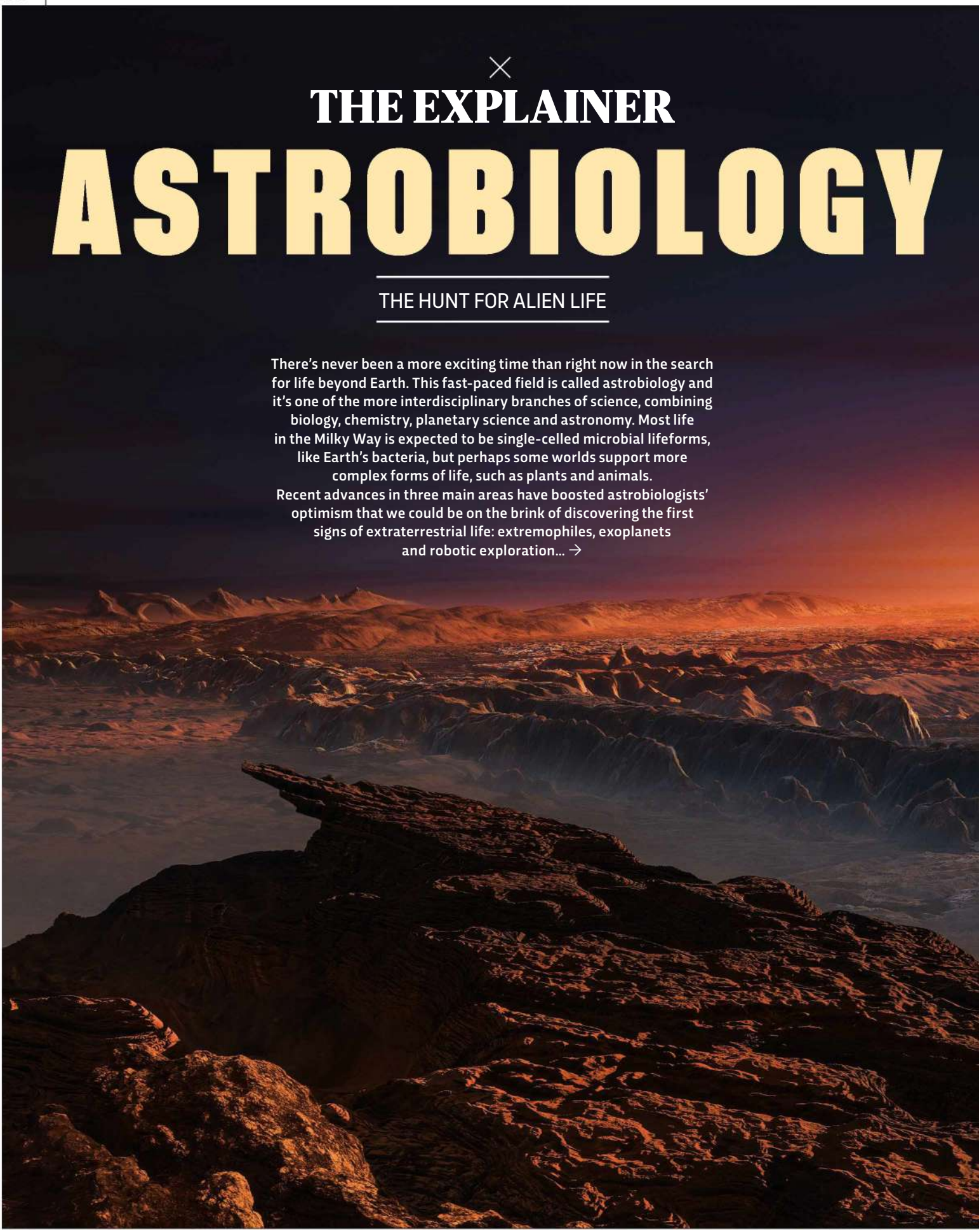
THE EXPLAINER

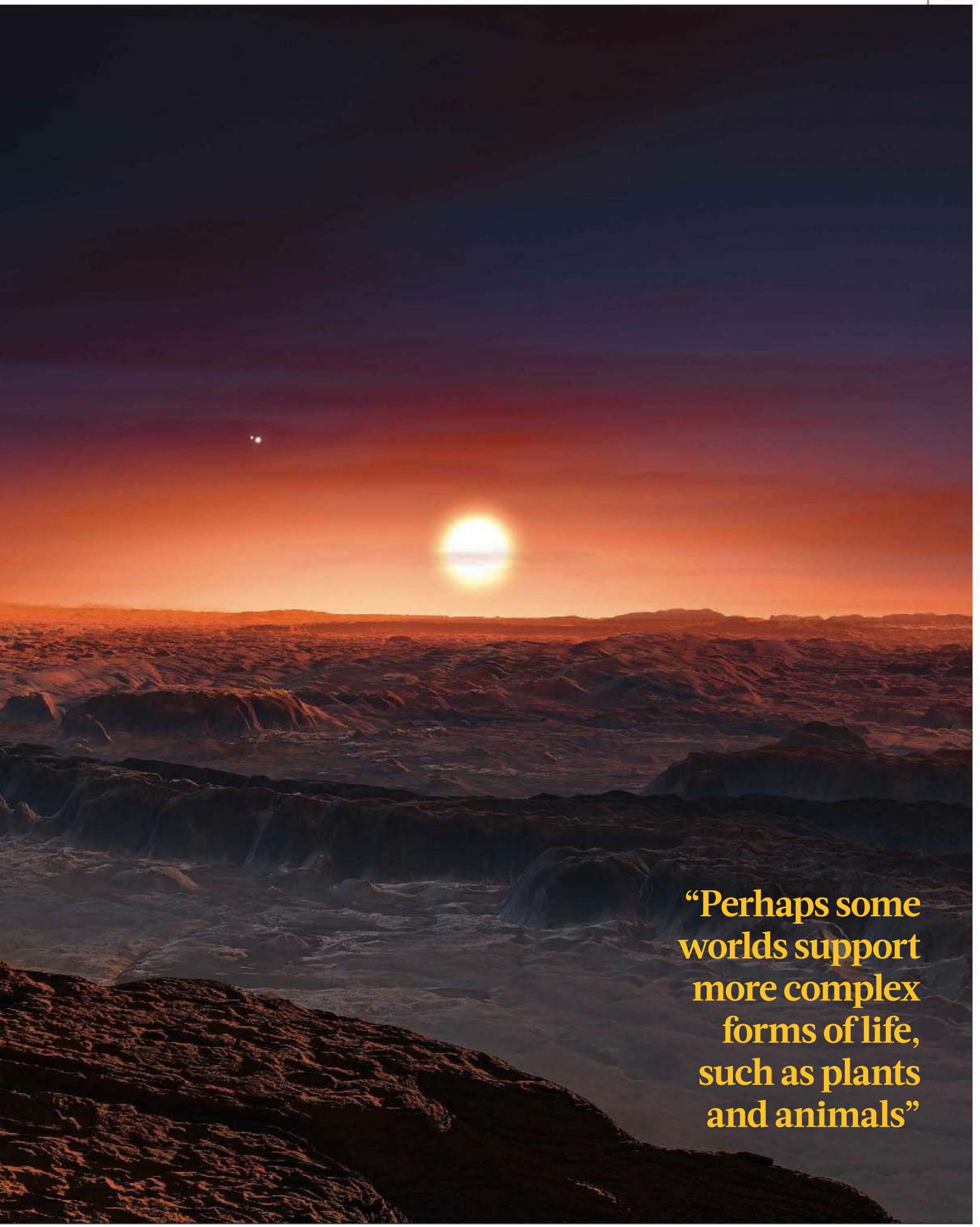
ASTROBIOLOGY

THE HUNT FOR ALIEN LIFE

There's never been a more exciting time than right now in the search for life beyond Earth. This fast-paced field is called astrobiology and it's one of the more interdisciplinary branches of science, combining biology, chemistry, planetary science and astronomy. Most life in the Milky Way is expected to be single-celled microbial lifeforms, like Earth's bacteria, but perhaps some worlds support more complex forms of life, such as plants and animals.

Recent advances in three main areas have boosted astrobiologists' optimism that we could be on the brink of discovering the first signs of extraterrestrial life: extremophiles, exoplanets and robotic exploration... →



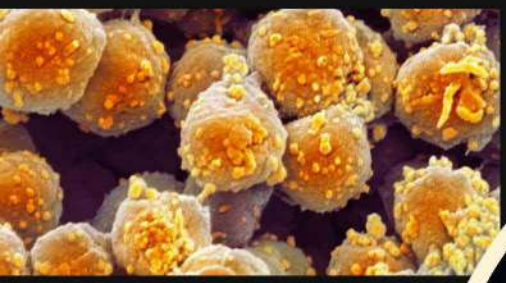


“Perhaps some worlds support more complex forms of life, such as plants and animals”

What three things are making astrobiologists so optimistic about finding life beyond Earth?

1. Extremophiles

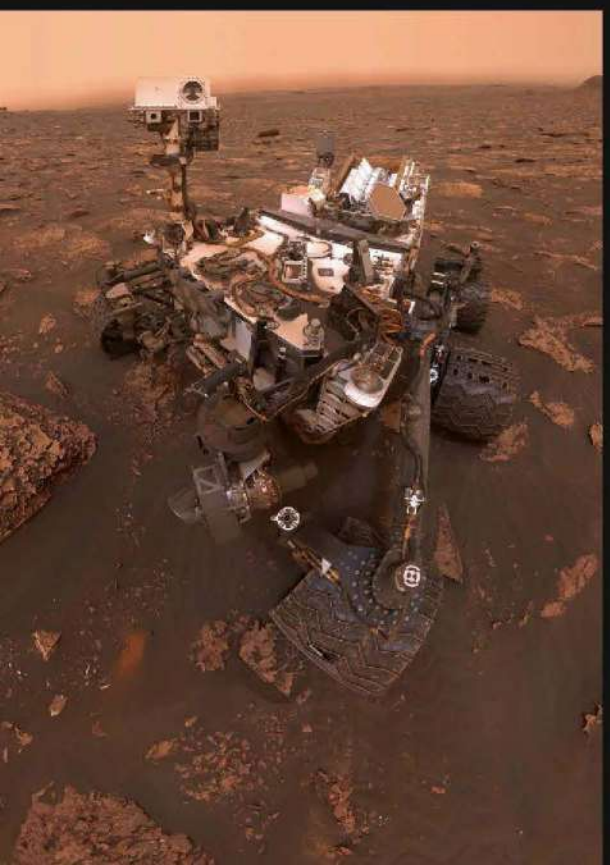
The more we learn about micro-organisms on Earth, the more we're surprised by the incredible adaptability of life. The hardiest lifeforms are known as extremophiles and they've been discovered surviving in some very inhospitable environments. They've been found in boiling-hot hydrothermal vents, beneath freezing-cold glaciers, in acidic pools of volcanic water, deep under Earth's crust, and even in high-radiation zones. Extremophiles teach astrobiologists about the outer limits for life and what sort of extraterrestrial environments might be habitable.



2. Exoplanets

Before 1992, the only planets we knew existed in the entire galaxy were the ones in our Solar System. Since then, our telescopes have discovered almost 5,400 worlds orbiting other stars – so-called extrasolar planets, or exoplanets. Most of the first exoplanets detected were bloated gas giants orbiting exceedingly closely to their suns – not the sort of world we believe could harbour life. But these were just the easiest to detect; we've since discovered smaller and smaller exoplanets orbiting further from their stars.

For astrobiology, the most exciting exoplanets are small, rocky, Earth-like ones orbiting the right distance from their stars so that their surface temperatures allow oceans of liquid water. These are potentially habitable worlds and would offer the best chances for extraterrestrial life. Future space-based telescopes would hopefully be able to detect signs of life – called biosignatures – in their atmosphere, such as the presence of oxygen gas released by photosynthesis.



3. Robotic exploration of the Solar System

Over recent decades, advances in robotics and the sophistication of scientific instruments have made our space probes more and more capable. There has been a fleet of orbiter, lander and rover missions launched to Mars, as well as probes sent to explore the outer planets, Jupiter and Saturn, and their families of moons.

Every time we visit another world we learn an enormous amount about its environment, active processes and its history – and invariably spark a whole slew of new questions to answer.

These space probes (as well as telescopes like Hubble) have revealed that a handful of planets and moons in the Solar System have potentially habitable environments that could support extraterrestrial life.

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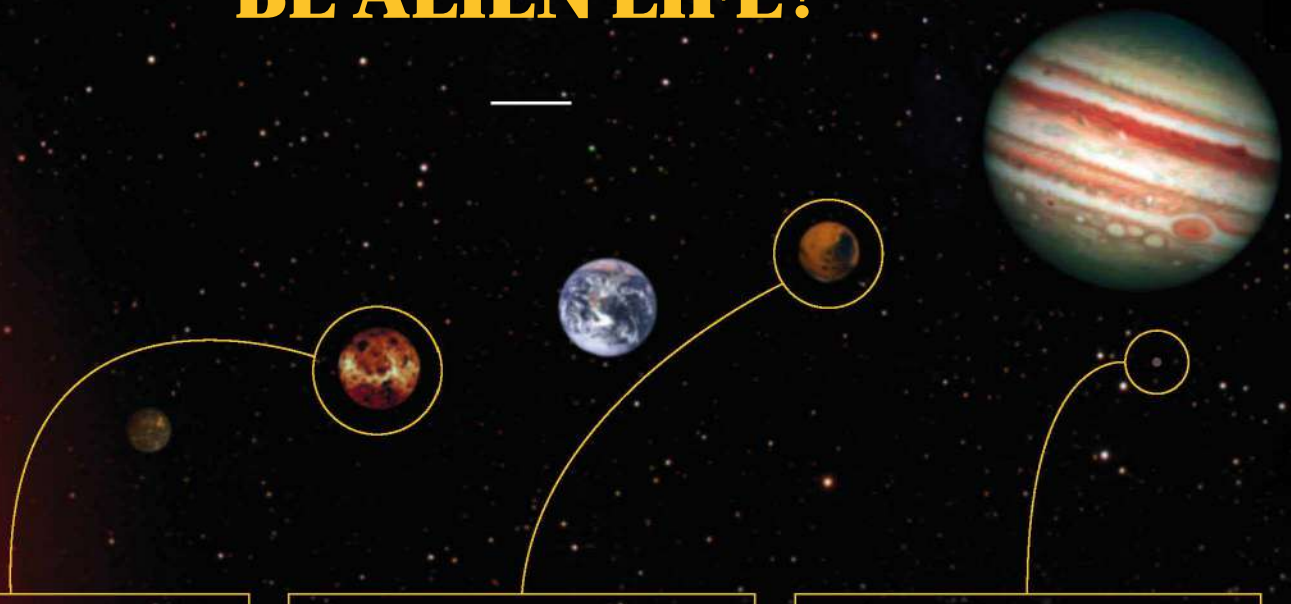
Could aliens be silicon-based?

All life on Earth needs liquid water to survive – it's very good at dissolving chemicals to support the reactions of biochemistry. Life here is also organic (built from complex molecules based on carbon atoms). It makes most sense for astrobiology to search for the sort of life we know is possible and we have a good idea how to detect. But could extraterrestrial life be based on a completely different kind of chemistry?

The element silicon sits just below carbon on the periodic table and so, in many ways, its chemistry is similar. But compared to carbon, silicon isn't nearly as good at forming stable chemical bonds and large, complex molecules. Alien life could be based on solvents other than liquid water, however: perhaps ammonia.

"It makes most sense for astrobiology to search for the sort of life we know is possible"

WHERE IN THE SOLAR SYSTEM COULD THERE BE ALIEN LIFE?



1.

VENUS

Today, the surface of Venus is a hellish landscape, hotter than an oven due to the greenhouse effect of the planet's thick carbon-dioxide atmosphere. But early Venus may have been more like Earth and there's a chance that any Venusian microbial life may have been able to survive by migrating high into the atmosphere. At altitudes of 50-60km (30-40 miles) the temperature is cooler and an aerial biosphere may exist in the clouds. The clouds are highly acidic, though, so Venusian life is probably unlikely.

2.

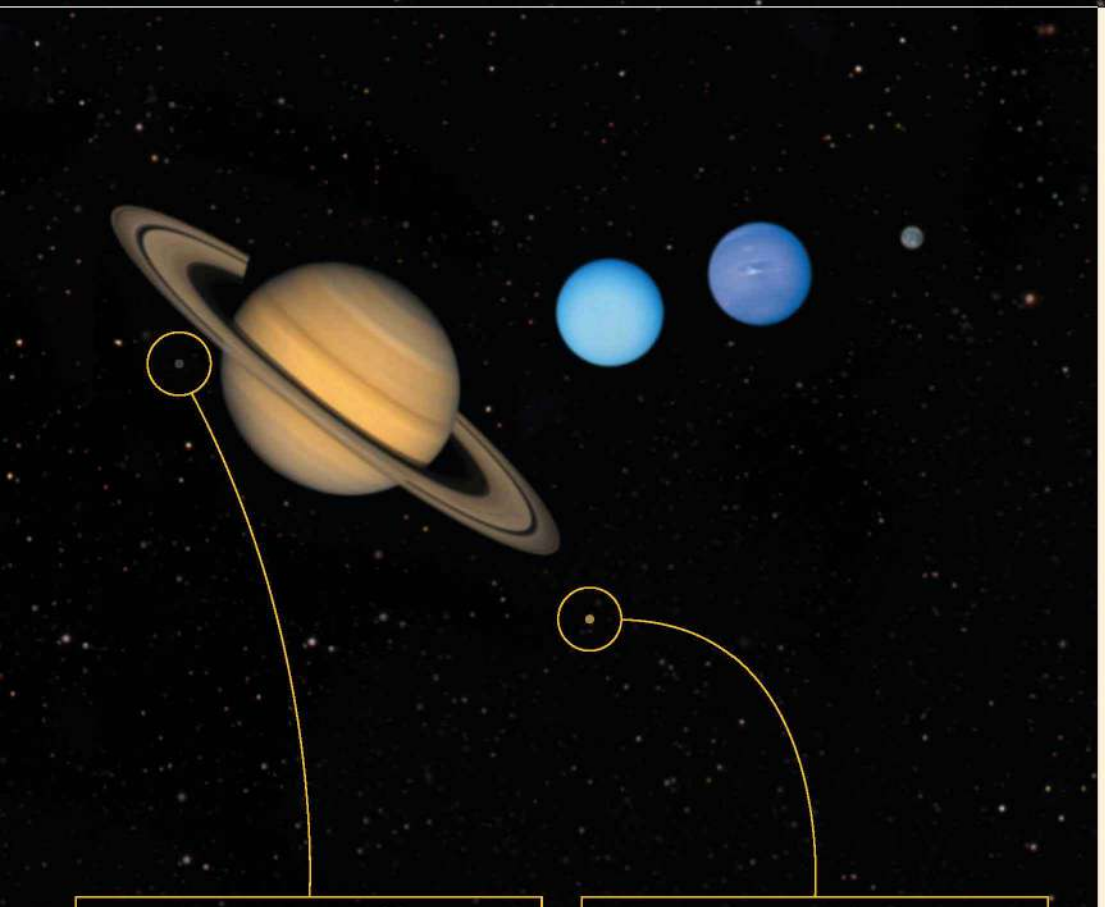
MARS

While the modern surface of Mars is a freeze-dried desert, blasted by ultraviolet rays from the Sun, around 3.8 billion years ago it's thought to have been much warmer and wetter. There's evidence of ancient lakes, river valleys and possibly even a large ocean covering the northern hemisphere. Organic molecules – the building blocks of life – are also thought to have been present on the Martian surface and so maybe the Red Planet developed life of its own. Any Martian microbes are probably long since extinct on the surface, but may survive deeper underground.

3.

EUROPA

Europa is one of the large moons orbiting Jupiter. Although its surface is hard-frozen ice, there's a deep ocean of liquid water beneath it, kept warm by 'tidal heating' from the moon flexing and distorting as it orbits in the gas giant's powerful gravitational field. This process may also drive hydrothermal vents on the Europan seafloor, which serve as oases for life in Earth's oceans. The key question for exploring Europa is, just how thick is its icy shell? And, would it be possible to get some kind of submersible probe beneath it to search for marine life?



4.

ENCELADUS

Enceladus is a moon of Saturn, but in many ways is like Europa. It has a cold, icy surface and an ocean of liquid water laying underneath that's in contact with the moon's rocky core. Jets of water squirt out of long fractures in the icy crust around the south pole and analysis of these has revealed the water is salty. Organic molecules have also been detected in these plumes and there's evidence for hydrothermal activity. So even though this alien ocean is thought to be pretty alkaline, it could still be habitable for life.

5.

TITAN

Titan orbits Saturn. It's a giant of a moon, and is the only moon in the Solar System to have a thick atmosphere that is rich with organic chemistry. Large lakes have been discovered around Titan's north pole, but these are filled with liquid ethane and methane, rather than water. It's still an open question as to whether life could be ethane-based rather than water-based, but Titan is a complex world and may harbour lifeforms with a biochemistry very different to those on Earth.

KEVYN GILL/WIKIPEDIA, NASA/JPL/SPACE SCIENCE INSTITUTE X4, GETTY IMAGES X2

Could aliens be intelligent?

Astrobiology is mostly focused on searching the Solar System for signs of hardy, single-celled life, or detecting atmospheric biosignatures in exoplanets. But could there be more complex life in the galaxy – alien plants and animals, or even intelligent, space-faring beings?

The galaxy is very old, and intelligent life could have evolved on another habitable world many millions of years before us, and potentially spread across the whole galaxy. But despite over 60 years of sporadic programmes listening for artificial radio transmissions or looking for signs of technological structures, we've not found any convincing evidence of intelligent life out there... yet.

by **PROF LEWIS DARTNELL**

Lewis is an astrobiologist at the University of Westminster and the author of Being Human *(£22, Bodley Head).*

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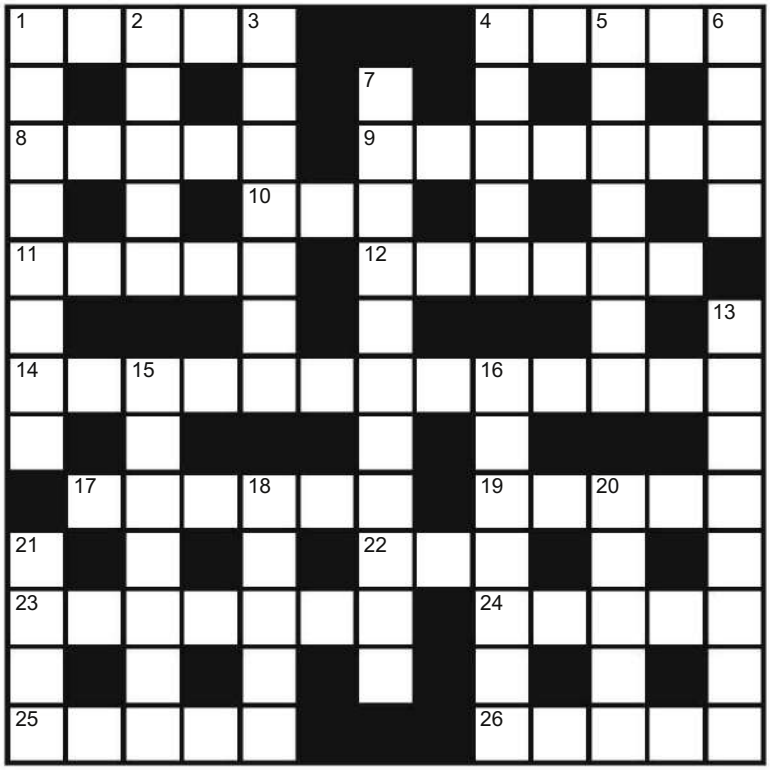

ACROSS

1 Fancy Nicholas embracing doubting Thomas (5)
4 Concerning that dame's not started to prepare (5)
8 Sound right as a conditioner (5)
9 Seafood delicacy? Throw rest out! (7)
10 Couple as well, by the sound of it (3)
11 Engineers with match to fix again (5)
12 Wrong storey for seafood (6)
14 Transport favourite drinker wearing large, soft shoe (6,7)
17 Resentful, having a beer (6)
19 Finished with a type of Italian food (5)
22 Previously used in poetry (3)
23 Proper turn by the French flower (7)
24 Managed church's farm (5)
25 Thing getting broken in darkness (5)
26 Left debtor further down (5)

DOWN

1 It prevents clear sight of waterfall (8)
2 Musical group without a safety measure (5)
3 Get back in central parade (7)
4 More business about puzzle (5)
5 Warp Ten, travelling around city (7)
6 Story's thread (4)
7 Circulation of family confused master (11)
13 Swimmer gets about, then has a rest (8)
15 Bringing up fruit - grapefruit, initially (7)
16 Prime order with one large risk (7)
18 Beginning to treat corrosion provides confidence (5)
20 Wines developed strength (5)
21 Honest old writer (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

SHARKS

Sink your teeth into the extraordinary biology of these varied and vital predators

GETTY IMAGES

PLUS

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Find out how forensic investigators use blood spatter analysis to make sense of murder

JAW DROPPING

Discover some of the biggest, smallest and strangest mouths in the animal kingdom

ON SALE 17 AUGUST

SF

POPCORN SCIENCE

Could adolescent reptiles learn martial arts?

Do you need more than pizza, surf slang and bright bandanas to bring out the heroes in four juvenile turtles?

by **STEPHEN KELLY**

You could be forgiven for thinking that the idea of teenage turtles who mutate into humanoid ninjas is a tad far-fetched. But you may be shell-shocked to learn that actually, in reality… it is.

"First of all," says Jeanette Wyneken, professor of biological sciences at Florida Atlantic University, "the chromosomes of a turtle and of a human don't match up. Turtles have more chromosomes than we do. And if your chromosomes don't match up, you often end up with genetic abnormalities called a 'teratology', a term that literally means monsters."

But let's ignore all of that. Let's suppose, somehow, there are mutant turtles that stand on two legs and say things like, "cowabunga, dude". Would their turtle physiology be able to adapt to humanoid anatomy?

"One big change," says Wyneken, "is that their centre of gravity would shift from their shoulders (while on four feet) to their hips when they stand on two." For a conventional four-legged turtle, this would mean toppling over from the weight of their shell, but "for humanoid turtles it's not much of an issue," says Wyneken, "because it would be more like a human wearing a big backpack."

The major difference, however, is that when a human wears a big backpack, that backpack doesn't also contain their ribs and spine. Whereas with turtles, the vertebral column is part of the shell; they can't take it off. According to Ivana Lezcano Serra, Wyneken's graduate student researcher, who specialises in turtle shells, this fact makes the new animated film *Teenage Mutant Ninja Turtles: Mutant Mayhem* difficult to take seriously.

"In the trailer, they're jumping around and doing all of these acrobatic stunts. But that fusion between spine and shell would make that very difficult," she says. "They simply wouldn't have the kind of flexible spine that would allow them to do backflips."

So they can't be mutants and they can't be ninjas. Can these turtles even be teenagers?!

"The new movie really focuses on the fact that they're young teenagers," says Lezcano Serra, "and that poses a problem for their abilities. The older turtles get, the more developed and ossified their shell becomes. They have more mineral in the bone. Younger turtles – their shells aren't going to be as hard. It's not going to protect them as much as they would probably want."

Even as adults, their shells wouldn't be bulletproof, says Lezcano Serra. "They're not like Captain America's shield. Shells protect turtles against things like shark attacks, but what a lot of people don't appreciate is that it isn't through strength, but flexibility. Steel can resist forces 1,000 times better than a shell can. A shell is more like a squeezy ketchup bottle: it deforms and then gets back into shape."

This flexibility not only applies to their shells, but also to their diet and environment. Red-eared slider turtles – the subspecies that the TMNT were originally based on – "can live just about anywhere there's water and food," says Wyneken, including the sewers of New York. But what of the teenage turtles' favourite food, pizza?

"Red-eared slider turtles eat a variety of things," says Wyneken. "The cheese may not be great for their digestive system. The carbs in the crust? Maybe in limited quantities. The vegetables would probably be fine. Turtles will eat tomato; just don't give it to them in the form of pizza. Could they eat pizza and survive? I think so. Could they eat it and be healthy? Not in the long run." **SF**

VERDICT

They *might* be able to live in the sewer and *occasionally* eat pizza, but saving a city with acrobatics and martial arts? Turtle-y ridiculous.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: JAMES OLSTEIN

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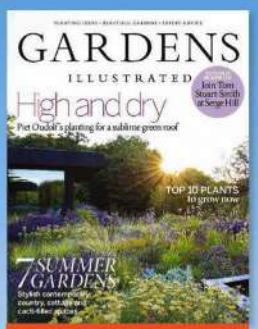

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